ORAL ARGUMENT NOT YET SCHEDULED

IN THE UNITED STATES COURT OF APPEALS
FOR THE DISTRICT OF COLUMBIA CIRCUIT

ELENA VENNER, *et al.*, *Petitioners*, v. UNITED STATES ENVIRONMENTAL PROTECTION AGENCY, *et al.*, *Respondents*.	Case No. 26-1038 Lead Case No. 26-1037 (and consolidated cases)

DECLARATION OF MARK Z. JACOBSON, PhD,
IN SUPPORT OF PETITIONERS' MOTION TO STAY
THE FINAL RULE PENDING REVIEW

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 Petitioners' Motion to Stay the Endangerment Finding rescission and repeal of vehicle emission standards (the "Repeal Rule") pending review. I offer the following expert opinions that the additional carbon dioxide (CO_2) that is emitted as a result of the Repeal Rule that otherwise would not be emitted will increase unhealthful local air pollution even

more in cities that are already polluted, separately from and in addition to causing global climate damage (such as enhancing coastal flooding, extreme weather events, agricultural loss and famine in some regions, ocean acidification, wildfires, and other impacts). As such, allowing such emissions, thereby slowing the vital transition toward the renewable energy that eliminates those emissions, at this pivotal time would be highly damaging to the health and economic wellbeing of the youth Petitioners in this case.

3. I served as an expert who was invited by the State of California to testify on May 18, 2009 at the U.S. Environmental Protection Agency Hearing in Arlington, Virginia, on the "Proposed Endangerment and Cause or Contribute Findings for Greenhouse Gases Under the Clean Air Act".[1] The second part of my testimony summarizes the direct health impacts of carbon dioxide through its increase in the chemical pollutants ozone and particulate matter (PM) in urban areas. My conclusion stated in the testimony is, "As such, reducing locally-emitted CO_2 reduces local air pollution deaths even if CO_2 in adjacent regions is not controlled." This is a scientific result based on two peer-reviewed scientific studies I performed.[2]

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[1] My oral and written testimony is provided here: https://web.stanford.edu/group/efmh/jacobson/PDFfiles/EPAEndang0509.pdf.

[2] Mark Z. Jacobson, *On the Causal Link between Carbon Dioxide and Air Pollution Mortality*, 35 Geophysical Rsch. Letters L03809 (2008), https://web.stanford.edu/group/efmh/jacobson/Articles/V/2007GL031101.pdf; Mark Z. Jacobson, *Enhancement of Local Air Pollution by Urban CO_2 Domes*, 44

4. I similarly testified at another EPA hearing (AMS-FRL-8772-7), on March 5, 2009 in Washington D.C., called "California State Motor Vehicle Control Standards: Greenhouse Gas Regulations: Reconsideration of Previous Denial of a Waiver of Preemption," in which I presented even more details on the impacts of local and global carbon dioxide emissions on air pollution health.[3]

5. Based on my previous testimony and my 37 years of experience studying air pollution and climate and their interactions, I can confidently say that there is no scientific basis to repeal EPA's Endangerment Finding for GHGs. In fact, the opposite is true: the scientific basis for the Finding has only become more extensive in the past 17 years as climate-change damage has worsened.

Background & Qualifications

6. I have two Bachelor's Degrees with Distinction from Stanford University, one in Civil Engineering and the other in Economics, both conferred in 1988. I earned a Master's Degree in Environmental Engineering from Stanford University, also conferred in 1988. I earned a second Master's Degree (1991) 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.

Env't Sci. Technology 2497 (2010), https://web.stanford.edu/group/efmh/jacobson/Articles/V/es903018m.pdf.

[3] The slides that I presented to EPA are located here: https://web.stanford.edu/group/efmh/jacobson/PDFfiles/0903EPACalif.pdf.

7. Since 1989, I have been researching the impacts of human emissions of gases (among them CO_2 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 Alaska, California, Colorado, Hawai‘i, Montana, New York, Pennsylvania, Tennessee, Washington, and Wisconsin (states where Petitioners live), and 150 countries to 100% clean, renewable energy by 2050. My peer reviewed research has demonstrated that fossil fuel energy is no longer needed to power all energy sectors of the 50 U.S. states and the 150 countries we examined. Instead, a complete transition away from fossil fuels is technically feasible by 2050 or earlier and economically beneficial. It will also reduce about 90 percent of the 7.4 million air pollution deaths per year worldwide (and over 100,000 per year in the U.S.), slow global warming, and increase net jobs. The cost savings, both in terms of energy costs and health and climate costs, are substantial, due in large part to the efficiencies gained in electrifying all-purpose energy, including transportation, and ending the perpetual mining, refining, transport and combustion of fossil fuels.

8. I served as an expert for the youth plaintiffs in the *Navahine v. Hawai`i Department of Transportation* case where the parties entered a settlement agreement designed to decarbonize the state transportation system.[4] I, along with other expert transportation expert witnesses, opined that it is both technically and economically feasible to transition from a predominantly fossil fuel-based energy system in the state of Hawai`i to a 100% clean, renewable energy system for all sectors, including transportation ideally by 2035 but no later than 2045. My research shows that there is no technical or economic impediment to transitioning Hawaii's transportation system off of fossil fuels, even though Hawai`i has been called "the most petroleum-dependent state in the Union."[5]

Carbon Dioxide Domes Increase Ozone and Particles, Thus Mortality

9. The Repeal Rule will increase CO_2 emissions from vehicle tailpipes.[6] Locally-emitted CO_2 from internal combustion engine (ICE) vehicles creates urban "CO_2 domes", or regions with CO_2 levels much higher than background levels. These CO_2 domes enhance local temperatures. Higher temperatures in cities, in turn,

[4] *Navahine v. Dep't of Transp.*, No. ICCV-22-0000631, Joint Stipulation and Order re: Settlement; Exhibit "A" (Haw. Cir. Ct. June 20, 2024).
[5] Hawai'i State Energy Office, State of Hawai'i Proposed Beneficiary Mitigation Plan Per Volkswagen Settlement Environmental Mitigation Trust Agreement. (2019). https://energy.hawaii.gov/wpcontent/uploads/2022/05/Hawaiis-Proposed-Beneficiary-Mitigation-Plan-for-the-VWEnvironmental-Mitigation-Trust-January-2019.pdf.
[6] EPA-HQ-OAR-2025-0194-0002; EPA-HQ-OAR-2025-0194-0003.

evaporate more water from the soil.[7] Both higher temperatures and higher water vapor independently increase local ozone concentrations[8] where ozone is already elevated and unhealthy or hazardous (i.e., in polluted air), inflaming and damaging respiratory airways, aggravating chronic lung disease, and increasing asthma attacks.[9] Higher temperatures and water vapor also increase particulate matter concentrations. The Repeal Rule will likely thus increase ozone and particulate matter in the cities[10] where some Petitioners reside, including C.E in Beloit, WI, Elena in San Luis Obispo, CA and Lakewood, CO, E.S. in Memphis, TN, Emma in La Jolla, CA, J.K. in Westchester County, NY, M.B in Madison, WI, M.D. in Garden Grove, CA, and Maya in Los Angeles (and Berkeley), CA. Such ozone increases will increase their risk of further respiratory harm up to and including premature death. Each of these Petitioners already resides in a town or city with an "F" (the worst) grade for ozone air quality according to the American Lung Association.[11]

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[7] Mark Z. Jacobson, *Enhancement of Local Air Pollution by Urban CO_2 Domes*, 44 Env't Sci. Technology 2497 (2010), https://web.stanford.edu/group/efmh/jacobson/Articles/V/es903018m.pdf; Mark Z. Jacobson, *On the Causal Link Between Carbon Dioxide and Air Pollution Mortality*, 35 Geophysical Rsch. Letters L03809 (2008), https://web.stanford.edu/group/efmh/jacobson/Articles/V/2007GL031101.pdf.

[8] *Id.*

[9] EPA, *Health Effects of Ozone Pollution*, https://www.epa.gov/ground-level-ozone-pollution/health-effects-ozone-pollution (last visited May 5, 2026).

[10] EPA-HQ-OAR-2025-0194-0002.

[11] American Lung Association, *State of the Air*, https://www.lung.org/research/sota (last visited May 5, 2026).

Katherine in Bethlehem, PA, lives in a "D" grade for particulate matter air quality, along with Emma, while M.B. and Maya have "F" grades for their residencies. Because these Petitioners already live in extremely unhealthy and harmful air, any further increase in ozone and particulate matter will only cause further harm. Indeed, according to the EPA's own projections of air quality changes[12], these regions will experience a disproportionate increase in ozone and particulate matter from the Repeal Rule.

10. In the United States, ambient air pollution (including $PM_{2.5}$, or particles smaller than 2.5 micrometers in diameter) from the production, processing, transport and end-use (e.g., combustion) of oil and gas alone kills about 91,000 people each year.[13] Coal mining, processing, and combustion increases the death rate to well beyond 100,000 per year.

11. It is important to recognize that vehicle emissions are not equivalent to power plant emissions in terms of health impacts. The intake fraction—how much emitted pollution is inhaled from a particular source—is 20-30 times higher for motor vehicles than power plants.[14] Thus, smaller amounts of pollutants that people

[12] EPA-HQ-OAR-2025-0194-0002.
[13] Karn Vohra et al., *The Health Burden and Racial-Ethnic Disparities of Air Pollution from the Major Oil and Gas Lifecycle Stages in the United States*, 11 Science Advances eadu2241 (2025).
[14] Piotr Holnicki et al., *Intra-urban Variability of the Intake Fraction from Multiple Emission Sources*, 9 Atmospheric Pollution Research 1184 (2018).

breathe in directly (e.g., $PM_{2.5}$, oxides of nitrogen-NO_x, reactive organic gases-ROG, and carbon monoxide-CO) from vehicles is more harmful to human health than the same amount of pollution emitted from power plants, because humans are far more likely to be exposed to the pollution from the motor vehicles that are ubiquitous with modern life.

12. The Repeal Rule will also increase $PM_{2.5}$, NO_x, ROG, and CO emissions from vehicle tail pipes over what would have otherwise occurred because of the decreased number of battery-electric vehicles (BEVs) and increased number of ICE vehicles on the roads because of the rescission of the GHG emission standards.[15] NO_x and ROGs can react with other atmospheric chemicals to create particulate matter and ozone.[16] $PM_{2.5}$, ozone, NO_x, and ROGs result in premature deaths, imposing health care costs as well as a financial burden on the country. The U.S. government statistically values a life at up to $14.2 million per person as of 2025, so even a small contribution to the death rate from fossil fuels can cost hundreds of millions of dollars in lost human life.[17]

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[15] EPA-HQ-OAR-2025-0194-0002; EPA-HQ-OAR-2025-0194-0003.
[16] EPA, *Basic Information about NO_2*, https://www.epa.gov/no2-pollution/basic-information-about-no2 (last visited May 5, 2026).
[17] US DOT, *Departmental Guidance on Valuation of a Statistical Life in Economic Analysis*, https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-on-valuation-of-a-statistical-life-in-economic-analysis (last visited May 5, 2026); Aaron Kearsley, *HHS Standard Values for Regulatory Analysis*, 2025 (Feb. 13, 2025),

13. Every new ICE vehicle increases demand for oil extraction. The average passenger vehicle car uses 509 gallons of gasoline per year, and over its fifteen-year life, a light-duty vehicle will use approximately 7,635 gallons of gasoline. The combustion of 7,635 gallons of gasoline over the life of one passenger car releases about 68 tons of CO_2 into the atmosphere.[18] It is not even possible to capture the CO_2 from the air (Direct Air Capture) without emitting even more CO_2 than was captured, because even in the best case of using renewable energy to capture CO_2, that renewable energy can then no longer replace a fossil source that emits more CO_2 than the amount being captured. As such, trying to capture CO_2 from the air is not a viable option since it only increases CO_2 in the air.[19]

14. EPA's analysis of these repealed GHG rules for vehicles looked at air quality improvement out to 2055 from the implementation of these rules beginning in 2027. Even if the repealed rules are reinstated five years in the future, the delay will damage air quality for five additional years, worsening air quality in the United

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https://aspe.hhs.gov/sites/default/files/documents/639756a60fbe7e51786bcec176ad52f1/Standard-RIA-Values-2025.pdf (U.S. Department of Health & Human Services values life at $13.6 million per person).

[18] EPA, *Greenhouse Gas Emissions from a Typical Passenger Vehicle*, https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle (last visited May 5, 2026).

[19] 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), https://web.stanford.edu/group/efmh/jacobson/Articles/I/149Country/149-Countries.pdf.

States compared with what it otherwise would be through 2060, with substantial costs to these Petitioners, society at large, and the government.

15. Allowing the Repeal Rule to go into effect for two years will lock in the emission of 942 million tons of additional CO_2 from vehicle tailpipes that otherwise would not have occurred. Even if the Rule goes back into effect in 2028, these 942 million tons will still have been emitted, and will stay in the atmosphere, due to the 15-year average lifespan of an ICE vehicle.

16. It would be virtually impossible to remove this amount of CO_2 from the atmosphere once it is emitted because, as stated, removing CO_2 from the air (Direct Air Capture) only increases the net CO_2 added to the air when the whole system is considered due to the large amount of energy needed to remove CO_2 from the air and the fact that using renewables for this energy prevents them from removing even more CO_2 by replacing a fossil-fuel source.[20] By far the best and fastest way to remove CO_2 from the air is to prevent it from getting into the air in the first place, which is why it is so vital the GHG emission standards for motor vehicles remain in place.

17. The additional fossil-fuel-powered vehicles that will be on the road because of the Repeal Rule will result in more lives lost, in illnesses, and in health costs, before even accounting for climate change damages, which are significant.

[20] *Id.*

Electric Vehicles Reduce Pollution and Energy Needs

18. One benefit of the GHG emission standards that EPA eliminated is that they were leading to more battery-electric vehicles (BEVs) on the roads in the U.S. BEVs are 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 are fossil-fuel powered vehicles with an internal combustion engine. BEVs use about 80% of the energy in their battery-stored electricity to move the vehicle, losing only 20% of the energy as heat. 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. Overall, 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.

19. I provide above a concrete example of the much higher BEV efficiency over a comparable ICE vehicle from the U.S. Department of Energy. For example, a comparison of the 2023 all-electric Ford F-150 Lightning extended range, 4WD (480 Wh/mi = 578.7 miles per gigajoule)[21] with the 2023 Ford F-150 8-cylinder 4WD flex-fuel truck running on gasoline (18 mpg = 139.1 miles per gigajoule),[22] indicates that the electric vehicle can go 4.2 times the distance as the gasoline version.

[21] https://www.fueleconomy.gov/feg/noframes/46327.shtml
[22] https://www.fueleconomy.gov/feg/byfuel/FFV2023.shtml

Therefore, it is my expert opinion that the Repeal Rule will increase energy consumption enormously in the U.S.

Rapid Transition to Renewable Energy and Electric Vehicles is Possible

20. In 2025, China entered a CO_2 emission plateau owing to large-scale deployment of renewable energy generation and EVs, whereas the U.S. saw increased CO_2 emissions following policy reversals, clean energy stagnation, and EV suppression.[23] BEVs are a central component to any energy transition away from fossil fuel reliance and reducing CO_2 emissions because transportation is the largest source of CO_2 emissions in the United States.[24] Transitioning to BEVs over ICE vehicles also aids in energy storage and grid stability, because EVs act as household batteries that can store electricity during high production and re-release during periods of high demand.[25] Such vehicle-to-home charging, in the limit, can cut American's energy costs by 61% and reduce their GHG emissions by 89%.

21. As of 2024, 11% of Chinese vehicles were EVs, while 2.7% of U.S. vehicles were EVs.[26] In 2024, 48% of new car sales in China were EVs, while the

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[23] Zhu Deng et al., *Global Carbon Emissions and Decarbonization in 2025*, Nature Reviews Earth & Env't (2026), https://doi.org/10.1038/s43017-026-00780-4.
[24] US EIA, *U.S. Energy-Related Carbon Dioxide Emissions, 2024*, https://www.eia.gov/environment/emissions/carbon/ (last visited May 5, 2026).
[25] Jiahui Chen et al., *Vehicle-to-home Charging can cut Costs and Greenhouse Gas Emissions Across the USA*, 10 Nature Energy 1458 (2025), https://www.nature.com/articles/s41560-025-01894-7.
[26] Share of cars currently in use that are electric, 2010 to 2024, https://ourworldindata.org/grapher/share-car-stocks-electric.

U.S. number was 10%.[27] In Norway, EVs made up 98% of new car sales in 2025; only 12 petrol-only and 67 diesel-only cars were sold in Norway in February 2026, meaning "the fossil car has thus practically been phased out of the new car market in Norway."[28]

22. ICE vehicles are not needed to meet the transportation needs in the United States or abroad and can be replaced by clean light to even heavy duty EVs that are already available to the United States and its citizens, provided the GHG emission standards for vehicles remain in place. More pollution from ICE vehicles means more health harms, including deaths. The Repeal Rule will cause serious and unnecessary harm to these Petitioners by significantly increasing local air pollution in areas where they live, climate change impacts on regional and global scales, and energy costs, with serious consequences for the young Americans, 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.

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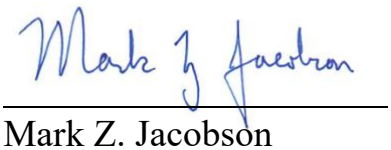
[27] Share of new cars sold that are electric, 2010 to 2024, https://ourworldindata.org/grapher/electric-car-sales-share?facet=none.

[28] Joshua Hill, *Fossil Cars all but Phased out in Norway as EV Sales Hit 98 pct, and Just 12 Petrol Cars Sold* (Mar. 4, 2026), https://thedriven.io/2026/03/04/fossil-cars-phased-out-as-norway-ev-sales-hit-98-pct-and-just-12-petrol-cars-sold/.

Executed on May 13, 2026 in 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*.

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Peer-Reviewed Papers Since 1990 (187 Total)

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