STATEMENT TO THE DELIVERING ON GOVERMENT EFFICIENCY SUBCOMMITTEE OF THE UNITED STATES HOUSE OF REPRESENTATIVES

Hearing on
Playing God with the Weather – A Disastrous Forecast

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CHRISTOPHER A. MARTZ

COMMITTEE FOR A CONSTRUCTIVE TOMORROW (CFACT)

cmartz@cfact.org

1. INTRODUCTION

I would like to thank the Chairwoman, Ranking Member and subcommittee for hosting this hearing on weather modification and geoengineering, and for giving me the opportunity to testify before you and provide my perspective, as a meteorologist, on this highly contentious issue.

My name is Chris Martz; I am a meteorologist and policy analyst for the Washington, D.C.-based Committee for a Constructive Tomorrow (CFACT). CFACT is a nonprofit, public policy think tank that was founded in 1985 to promote a free-market perspective on climate, environmental and energy policy. My role at CFACT involves a number of responsibilities: I write op-eds, I do media, and am responsible for writing the monthly climate fact-check. Currently, I am in the planning stages of developing an online climate database for CFACT's Climate Depot, which will include interactive charts, graphs and tables that will be easily accessible to the general public.

In May, I graduated from Millersville University of Pennsylvania with my Bachelor of Science (BSc) degree in meteorology and minor in emergency management.

With that, my testimony will primarily focus on two important things:

1. Distinguishing airplane condensation trails from "weather modification" (e.g., cloud seeding) and "geoengineering," particularly solar radiation modification (SRM) proposals to counteract global warming.

2. Why SRM in particular should be prohibited given the uncertainties about its effects on both the environment and life on Earth, as well as some uncertainties regarding global warming and climate change.

2. CONDENSATION TRAILS

In social media circles, people often confuse weather modification (e.g., cloud seeding) with geoengineering. To complicate matters further, photographs or videos of ominous-looking line-shaped clouds—aircraft-induced condensation trails—are shared to social media and are said to be evidence that the federal government is "manipulating" the weather through cloud seeding. Some users go so far as to assert that the government can steer hurricanes, which was a popular narrative in some online circles after Hurricane Helene's extratropical remnants ravaged eastern Tennessee, northeastern Georgia and the Carolina backcountry last fall.[1]

Condensation trails (or "contrails" for short) are high-altitude line-shaped ice crystal clouds that form behind jet aircraft.[2] [3] The exhaust from aircraft is composed primarily of invisible water vapor (H_2O) and carbon dioxide (CO_2), as well as some

[1] National Oceanic and Atmospheric Administration. "Fact Check: Debunking Weather Modification Claims." Last modified October 23, 2024. https://www.noaa.gov/news/fact-check-debunking-weather-modification-claims.

[2] American Meteorological Society. "Condensation Trail." In *Glossary of Meteorology*. Last modified March 26, 2024. Accessed September 10, 2025. https://glossary.ametsoc.org/wiki/Condensation_trail.

[3] United States Environmental Protection Agency. "Frequent Questions about Geoengineering: Contrails." Last modified August 21, 2025. Accessed September 10, 2025. https://www.epa.gov/geoengineering/frequent-questions#contrails.

other carbon-based particles like soot, which can act as cloud condensation nuclei.[3] These nuclei lower the saturation vapor pressure through the "solute effect," providing surfaces for water vapor in the air to easily condense onto as that air is lifted and cooled to saturation (e.g., Appleman, 1953; Schumann, 1996).[4] [5] Those droplets then freeze around the nuclei, forming these white cloud streaks across the sky.

Contrails form at altitudes above 20,000 feet. They do not block out a significant portion of incoming sunlight. In fact, contrails (and cirriform clouds in general) actually have a ***net warming*** effect on the planet because their thin physical characteristics allow most photons of incoming solar radiation to filter through the atmosphere, but absorb and reemit infrared radiation (IR) coming up from the ground and lower atmospheric layers, which slightly enhances the Earth's greenhouse effect (Lynch, 1996).[6]

Although contrails are undoubtedly more common today than even just 30 years ago because of increased air traffic, they are not a new phenomenon. The photograph below in Fig. 1, for example, shows contrails in the sky over London during the Battle of Britain in September 1940.[7] There are ***no compelling lines of evidence*** that aircraft condensation trails are deliberately created to alter weather patterns or "block out" solar radiation.

[4] Appleman, H., 1953: The Formation of Exhaust Condensation Trails by Jet Aircraft. *Bull. Amer. Meteor. Soc.*, **34**, 14–20, https://doi.org/10.1175/1520-0477-34.1.14.

[5] Schumann, U. (1996). Über Bedingungen zur Bildung von Kondensstreifen aus Flugzeugabgasen. *Meteorologische Zeitschrift*, *5*(1), 4–23. https://doi.org/10.1127/metz/5/1996/4.

[6] Lynch, D. K. (1996). Cirrus clouds: Their role in climate and Global Change. *Acta Astronautica*, *38*(11), 859–863. https://doi.org/10.1016/s0094-5765(96)00098-7

[7] Mayers, Renaud. "Contrails over London: A Glimpse into History." Defensionem, December 14, 2023. https://defensionem.com/contrails-over-london-a-glimpse-into-history/.

***Fig. 1**. Condensation trails over London, UK in September 1940 during the Battle of Britain.*[7]

3. Weather Modification and Cloud Seeding

Weather modification, on the contrary, is the deliberate attempt by humans to alter local weather patterns. The most common example of weather modification is "cloud seeding," which involves either:

1. The injection of tiny hygroscopic (water-attracting) particles like salt (NaCl) into the base of liquid or mixed-phase convective clouds to accelerate droplet coalescence to enhance rainfall or reduce hailstone size,[8] [9] or,

2. The introduction of particles such as silver iodide (AgI) and dry ice (solid CO_2) to orographic wintertime clouds with the intention of enhancing the transition

[8] United States Environmental Protection Agency. "Frequent Questions about Geoengineering." Washington, DC: U.S. Environmental Protection Agency, last modified August 28, 2025. https://www.epa.gov/geoengineering/frequent-questions.

[9] "Cloud Seeding Technology: Assessing Effectiveness and Other Challenges." U.S. Government Accountability Office, December 19, 2024. https://www.gao.gov/products/gao-25-107328.

from supercooled liquid water droplets (water that is below freezing, but remains liquid) to ice-phase hydrometeors, which is aimed at increasing precipitation in drought-stricken regions (e.g., to increase snowpack in the intermountain west for water availability).[8] [9]

The U.S. government has been involved in funding cloud seeding research and experimentation since the 1940s.

For instance, during Project Cirrus (a joint venture between General Electric, the Naval Research Laboratory and Army Signal Corps) in October 1947, an Air Force B-17 intercepted a hurricane 415 miles (668 km) off the Jacksonville, Florida coastline and injected dry ice into the storm to see what happened, but the results were inconclusive.[8] [10]

Another example of government-funded weather modification was Project Stormfury, which ran from 1962 to 1983.[11] The idea behind this was to attempt weakening hurricanes before landfall. The theory was that if pilots could seed clouds with silver iodide in the outer rainbands of a tropical cyclone (of which hurricanes are a subset of), then that would cause a secondary eyewall to form around the original eyewall (the "ring" of most intense winds encircling the eye).[11] This would, in theory, result in the inner eyewall collapsing through partial conservation of angular momentum, in turn reducing the wind speeds (NOAA, 2014; Willoughby et al., 1985).[11] [12] However, despite experimentation on four hurricanes initially appearing to have been a successful endeavor, it was later discovered in Willoughby et al. (1982) that intense hurricanes often undergo eyewall replacement cycles (EWRCs) on their own, which

[10] Griffin-Elliott, Thia. "70th Anniversary of the First Hurricane Seeding Experiment." NOAA's Atlantic Oceanographic and Meteorological Laboratory, October 9, 2024. https://www.aoml.noaa.gov/hurricane_blog/70th-anniversary-of-the-first-hurricane-seeding-experiment/.

[11] "Project Stormfury." NOAA's Atlantic Oceanographic and Meteorological Laboratories, 2014. https://www.aoml.noaa.gov/hrd/hrd_sub/sfury.html.

[12] Willoughby, H. E., D. P. Jorgensen, R. A. Black, and S. L. Rosenthal, 1985: Project STORMFURY: A Scientific Chronicle 1962–1983. *Bull. Amer. Meteor. Soc.*, **66**, 505–514, https://doi.org/10.1175/1520-0477(1985)066<0505:PSASC>2.0.CO;2.

suggested that cloud seeding had little material effect.[13] These inconclusive results ultimately led to the disbanding of Project Stormfury a year later in 1983.

In recent years, there have been no known efforts to modify large-scale weather patterns. However, the federal government does support cloud seeding efforts at the state and local levels, according to the U.S. Environmental Protection Agency (EPA).[8] These activities are aimed at alleviating droughts through snowpack or rainfall enhancement, primarily in the Colorado River Basin, which has faced water storage problems, due to severe drought conditions over much of the last 25 years superimposed onto increased water demand from a growing population.

A report from the Government Accountability Office (GAO) published in December 2024 noted that,

> *"[I]n 2023 the Bureau of Reclamation provided a $2.4 million grant to the Southern Nevada Water Authority for cloud seeding operations in Colorado, Utah, and Wyoming intended to benefit the Colorado River and to better understand the efficacy of cloud seeding… [and] [t]he National Science Foundation (NSF) awarded nearly $3.5 million to a 2017 Idaho field experiment to observe and model cold season cloud seeding."* [9]

All in all, cloud seeding is incapable of altering weather patterns at what Orlanski (1975) defines as mesoscale level (particularly meso-α) or greater (≥200 km in horizontal distance; about the distance between Washington, D.C. and Philadelphia, Pennsylvania).[14] Even on the meso-β (20-200 km), meso-γ (2-20 km) and microscale (<2 km), studies have shown that cloud seeding only enhances precipitation by up to 15% compared to control areas, but that number can be much lower depending on

[13] Willoughby, H. E., J. A. Clos, and M. G. Shoreibah, 1982: Concentric Eye Walls, Secondary Wind Maxima, and The Evolution of the Hurricane vortex. *J. Atmos. Sci.*, **39**, 395–411, https://doi.org/10.1175/1520-0469(1982)039<0395:CEWSWM>2.0.CO;2.

[14] Orlanski, Isidoro. "A Rational Subdivision of Scales for Atmospheric Processes." *Bulletin of the American Meteorological Society* 56, no. 5 (1975): 527–30. http://www.jstor.org/stable/26216020.

cloud type (e.g., Homoud et al., 2024).[15] Given that there also isn't a 100% success rate, cloud seeding is only ***slightly effective*** at small scales and ***largely ineffective*** at large scales.

While the GAO report found that silver iodide does not pose a significant danger to the environment or public health at current levels because it is virtually insoluble in pure water, if it is released at high enough concentrations from cloud seeding over one particular area over several years, some peer-reviewed research has demonstrated that bioaccumulation in soil over time can negatively affect both plant fertility and biota living in terrestrial and aquatic ecosystems (e.g., Fajardo et al., 2016).[8] [16]

According to the EPA, nine U.S. states currently facilitate active cloud seeding programs: California, Colorado, Idaho, Nevada, New Mexico, North Dakota, Texas, Utah, and Wyoming, although most of these are funded by the state or local-level governments.[8] Even so, there are strict laws and regulations in place about exactly when and where cloud seeding can be done in the states permitting it and all activities must be reported to the National Oceanic and Atmospheric Administration (NOAA) under WMRA.[17] Failure to comply may result in the offender(s) paying up to $10,000 in fines.[16] Both Tennessee and Florida have passed laws banning weather modification of any kind in 2024 and 2025, respectively.[8]

4. Geoengineering and Solar Radiation Modification (SRM)

Geoengineering is a bit different from weather modification—not only in terms of what it entails, but also in terms of scale.

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[15] Al Homoud, Marya, Stavros-Andreas Logothetis, Yosra SR Elnaggar, and Ashraf Farahat. 2024. "Assessment of the Cloud Seeding Efficiency over Tom Green County Texas, USA" *Atmosphere* 15, no. 12: 1506. https://doi.org/10.3390/atmos15121506.

[16] Fajardo C, Costa G, Ortiz LT, Nande M, Rodríguez-Membibre ML, Martín M, Sánchez-Fortún S. Potential risk of acute toxicity induced by AgI cloud seeding on soil and freshwater biota. Ecotoxicol Environ Saf. 2016 Nov;133:433-41. doi: 10.1016/j.ecoenv.2016.06.028. Epub 2016 Aug 9. PMID: 27517140.

[17] "NOAA Library: Weather and Climate Collections: Weather Modification Project Reports." NOAA Central Library. Accessed September 11, 2025. https://library.noaa.gov/weather-climate/weather-modification-project-reports.

Specifically, it is the [proposed] intentional attempt to counteract global warming by either (a) removing CO_2 from the atmosphere or (b) altering the amount of sunlight that reaches the Earth's surface on a large scale.[18] The latter method, called solar radiation modification (SRM), is the more widely-known and controversial method.

SRM involves a number of different procedures, including, but not limited to:

1. **Marine Cloud Brightening (MCB)**: The addition of tiny particles into the lower atmosphere over the ocean to increase the reflectivity (albedo) of clouds.[18] [19]

2. **Cirrus Cloud Thinning (CTT)**: Seeding high-altitude cirriform clouds to reduce their optical thickness as a means to speed up the rate of emission of outgoing longwave radiation (OLR) to outer space.[18] [19]

3. **Stratospheric Aerosol Injection (SAI)**: The addition of sulfur dioxide (SO_2) into the stratosphere (the atmospheric layer above the troposphere, where we live), which then chemically reacts and becomes highly reflective sulfate aerosols (Kroll et al., 2018) (see Table 1).[20] This would be similar to the global cooling effects induced by major volcanic eruptions (e.g., Mount Tambora in 1815; El Chichón in 1982; Mount Pinatubo in 1991).[18] [19]

[18] "About Geoengineering." EPA, July 11, 2025. https://www.epa.gov/geoengineering/about-geoengineering.

[19] Lee, J.-Y., J. Marotzke, G. Bala, L. Cao, S. Corti, J.P. Dunne, F. Engelbrecht, E. Fischer, J.C. Fyfe, C. Jones, A. Maycock, J. Mutemi, O. Ndiaye, S. Panickal, and T. Zhou, 2021: Future Global Climate: Scenario-Based Projections and Near-Term Information. In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 553–672, doi: 10.1017/9781009157896.006.

[20] Kroll, Jay A., Benjamin N. Frandsen, Henrik G. Kjaergaard, and Veronica Vaida. "Atmospheric Hydroxyl Radical Source: Reaction of Triplet SO_2 and Water." *The Journal of Physical Chemistry A* 122, no. 18 (April 17, 2018): 4465–69. https://doi.org/10.1021/acs.jpca.8b03524.

Step 1: Sulfur dioxide (SO_2) reacts with hydroxyl radicals
$$SO_2 + OH\bullet \rightarrow HOSO_2\bullet$$
Step 2: The $HOSO_2$ radical then reacts with diatomic oxygen (O_2) to form sulfur trioxide (SO_3) and hydroperoxyl (HO_2) radical.
$$HOSO_2\bullet + O_2 \rightarrow SO_3 + HO_2\bullet$$
Step 3: Since SO_3 is highly reactive, it combines with water vapor (H_2O) to form sulfuric acid (H_2SO_4)
$$SO_3 + H_2O \rightarrow H_2SO_4$$
Step 4: Sulfuric acid molecules then condense into liquid sulfate aerosols with diameters of 0.1-1 μm

Table 1. *Formation of sulfate aerosols.*[20]

Proposals to use SAI to mitigate global warming have gained traction in recent years and are far from a conspiracy theory. In March 2021, a committee of the U.S. National Academy of Sciences (NAS) suggested that the "[U].S. should pursue a research program for solar geoengineering" for "[c]limate mitigation and adaptation" with up to $200 million in funding for the first five years of such a program.[21] What's more, the United Nations Intergovernmental Panel on Climate Change (IPCC) says that, "SAI is the most researched SRM method, with *high agreement* that it could limit warming to below 1.5°C" (IPCC, 2018: Global Warming of 1.5°C, p. 350).[22]

If implemented, radiative transfer calculations estimate that SAI could reduce the globally-averaged incoming solar radiation flux by 1-8 W/m^2, which would more than

[21] "New Report Says U.S. Should Cautiously Pursue Solar Geoengineering Research to Better Understand Options for Responding to Climate Change Risks." National Academies, March 21, 2021. https://www.nationalacademies.org/news/2021/03/new-report-says-u-s-should-cautiously-pursue-solar-geoengineering-research-to-better-understand-options-for-responding-to-climate-change-risks.

[22] Intergovernmental Panel on Climate Change (IPCC). Strengthening and Implementing the Global Response. In: *Global Warming of 1.5°C: IPCC Special Report on Impacts of Global Warming of 1.5°C above Pre-Industrial Levels in Context of Strengthening Response to Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*. Cambridge University Press; 2022:313-444.

offset the current estimated energy imbalance, which is on the order of 1.12 ± 0.48 W/m^2 (Loeb et al., 2021).[23] The reason sulfate aerosols are so effective at reflecting sunlight is because their diameter range (0.1-1 μm) is comparable to the wavelength of incoming shortwave ultraviolet (0.1-0.4 μm) and visible (0.4-0.7 μm) light.

5. Why I Oppose Weather Modification and Solar Geoengineering

In regard to whether or not cloud seeding should be banned, I am of the view that we should minimize our interference with nature.

As a meteorologist, I can appreciate how cloud seeding experiments have contributed to the advancement of our understanding of cloud physics. However, trying to manipulate the weather, even on localized scales, can have unintended downstream consequences. Although ***silver iodide is not an immediate danger*** to us and there is no indication that bad faith actors are deliberately trying to poison the air we breathe, ***the long-term effects of silver iodide precipitating into our soil and water tables have not been studied enough*** thoroughly enough to definitively conduct a cost-benefit analysis. However, ***the dry ice method of glaciogenic cloud seeding is far more environmentally friendly*** since the pellets sublimate into CO_2 (Kochtubajda & Lozowski, 1985; Purandare et al., 2023),[24] [25] which is harmless.

With respect to solar geoengineering, such a practice is ethically preposterous because using the planet as a test monkey for emerging technologies poses all sorts of risks. Among these risks from SAI highlighted by the EPA are stratospheric ozone depletion, increased risk of sulfur deposition (acid rain) and soil acidity, and reduced

[23] Loeb, N. G., Johnson, G. C., Thorsen, T. J., Lyman, J. M., Rose, F. G., & Kato, S. (2021). Satellite and ocean data reveal marked increase in Earth's heating rate. *Geophysical Research Letters*, 48, e2021GL093047. https://doi.org/10.1029/2021GL093047.

[24] Kochtubajda, B., and E. P. Lozowski, 1985: The Sublimation of Dry Ice Pellets Used for Cloud Seeding. *J. Appl. Meteor. Climatol.*, **24**, 597–605, https://doi.org/10.1175/1520-0450(1985)024<0597:TSODIP>2.0.CO;2.

[25] Purandare, Abhishek, Wouter Verbruggen, and Srinivas Vanapalli. "Experimental and Theoretical Investigation of the Dry Ice Sublimation Temperature for Varying Far-Field Pressure and CO2 Concentration." *International Communications in Heat and Mass Transfer*, 107042, 148, no. November 2023 (September 23, 2023). https://doi.org/10.2139/ssrn.4462700.

crop yields due to decreased incoming solar radiation flux.[17] Simply put, the EPA concludes that,

> *"Current understanding of risks and benefits is limited by uncertainties in the observations and modeling tools used to examine solar geoengineering impacts. There isn't enough information available to fully understand the unintended consequences of solar geoengineering."* [18]

Increased acid rain risk is one of the primary concerns of SAI. Visoni et al. (2018) found that sulfate geoengineering could increase acid deposition by 5.2% if SAI is deployed,[26] but there remains no consensus on this matter. A separate study published last year in the journal of *Global Environmental Change Advances* found that acid deposition should continue to decrease regardless of whether geoengineering technologies are utilized or not.[27]

There is also the question of whether such large-scale climate intervention is even necessary given the uncertainties regarding climate change and the cost of doing it.

While the planet has warmed up over the last 175 years, and at least ***some of that warming is due to mankind's CO_2 emissions***, ***there is uncertainty as to exactly how much influence humans have exerted***. This uncertainty arises from the fact that:

1. Models produce too much warming with the known physics, so modelers artificially tune their models to the instrumental surface temperature record (Voosen, 2016; Mauritsen & Roecker, 2020; U.S. DOE CWG, 2025) to bring the

[26] Visioni, D., Pitari, G., Tuccella, P., and Curci, G.: Sulfur deposition changes under sulfate geoengineering conditions: quasi-biennial oscillation effects on the transport and lifetime of stratospheric aerosols, Atmos. Chem. Phys., 18, 2787–2808, https://doi.org/10.5194/acp-18-2787-2018, 2018.

[27] Rubin, H.J., C.-E. Yang, F.M. Hoffman, and J.S. Fu. "Projected Global Sulfur Deposition with Climate Intervention." *Global Environmental Change Advances* 3 (December 2024): 100011. https://doi.org/10.1016/j.gecadv.2024.100011.

simulated temperature change to a realistic range.[28] [29] [30]

2. The uncertainty in the magnitude of the natural energy flows in and out of the atmosphere, as measured by CERES satellites, is about 5-6 times larger than the estimated Earth energy imbalance (EEI). In layman terms, this means that ***most of the warming could be natural*** or anthropogenic, ***but scientists could never know*** with absolute certainty.

3. There is ***no unique "fingerprint" of anthropogenic warming***. All warming, natural or man-made, would involve (a) more warming over land than in the oceans and (b) more warming in higher latitudes than in the mid-latitudes and tropics (e.g., Compo & Sardeshmukh, 2008).[31] Although stratospheric cooling, which has been observed, is without a doubt due to CO_2 forcing (first demonstrated in Manabe & Strickler, 1964)[32] and is commonly claimed to be a "fingerprint" that proves global warming in the troposphere is man-made (e.g., Santer at al., 2023),[33] it is not the same thing because the mechanisms of heat transfer in the lower atmosphere are vastly more complex physically than the upper atmosphere since heat transfer in the troposphere involves both radiation and convection.

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[28] Paul Voosen, Climate scientists open up their black boxes to scrutiny. *Science* **354**,401-402(2016).DOI:10.1126/science.354.6311.401.

[29] Mauritsen, T., & Roeckner, E. (2020). Tuning the MPI-ESM1.2 global climate model to improve the match with instrumental record warming by lowering its climate sensitivity. *Journal of Advances in Modeling Earth Systems*, 12, e2019MS002037. https://doi.org/10.1029/2019MS002037

[30] Climate Working Group (2025) A Critical Review of Impacts of Greenhouse Gas Emissions on the U.S. Climate. Washington DC: Department of Energy, July 23, 2025

[31] Compo, G.P., Sardeshmukh, P.D. Oceanic influences on recent continental warming. *Clim Dyn* **32**, 333–342 (2009). https://doi.org/10.1007/s00382-008-0448-9

[32] Manabe, S., and R. F. Strickler, 1964: Thermal Equilibrium of the Atmosphere with a Convective Adjustment. *J. Atmos. Sci.*, **21**, 361–385, https://doi.org/10.1175/1520-0469(1964)021<0361:TEOTAW>2.0.CO;2.

[33] B.D. Santer, S. Po-Chedley, L. Zhao, C. Zou, Q. Fu, S. Solomon, D.W.J. Thompson, C. Mears, & K.E. Taylor, Exceptional stratospheric contribution to human fingerprints on atmospheric temperature, Proc. Natl. Acad. Sci. U.S.A. 120 (20) e2300758120, https://doi.org/10.1073/pnas.2300758120 (2023).

To elaborate on point two, the direct radiative forcing of doubling atmospheric CO_2 concentrations is estimated to be 3.7 ± 0.4 W/m^2 (IPCC TAR, 2001, p. 357).[34] This forcing creates an EEI that leads to a gradual warming of the lower atmosphere, all else being equal. The current EEI, as previously noted, is estimated to be 1.18 ± 0.48 W/m^2 (Loeb et al., 2021).[23] However, the radiation flux into Earth's atmosphere is 239 ± 3.3 W/m^2 of absorbed solar radiation (ASR) averaged over the course of a year (Stephens et al., 2012), the margin of error of which is nearly six times larger than the EEI.[35]

The magnitude of warming and the rate at which it occurs make all the difference in whether global warming is cause for alarm that requires economic decarbonization and/or large-scale interventions like SRM, or is largely unimportant in terms of environment and public health.

Just how much warming will occur is dependent on "equilibrium climate sensitivity" (ECS), which is the amount of warming that results from doubling atmospheric CO_2 levels plus any feedbacks that amplify or dampen the slight increase in temperature caused directly by CO_2 and other greenhouse gases (GHGs).

- If ECS is ≥3°C, then the climate system is highly sensitive to GHGs, and climate warming is therefore a concern.

- If ECS is <3°C, then the climate system is largely insensitive to GHGs, and warming impacts are exaggerated. This seems to be the likely case given that we have not seen increases in most types of extreme events, climate models overestimate warming (U.S. DOE CWG, 2025)[30] and the state of human welfare has never been better than it is today by nearly every measurable metric.

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[34] Ramaswamy, V., O. Boucher, J. Haigh, D. Hauglustaine, J. Haywood, G. Myhre, T. Nakajima, G. Y. Shi, and S. Solomon. 2001. "Radiative Forcing of Climate Change." In Climate Change 2001: The Scientific Basis, edited by J. T. Houghton, Y. Ding, D. J. Griggs, M. Noguer, P. J. van der Linden, X. Dai, K. Maskell, and C. A. Johnson, 349–416. Cambridge: Cambridge University Press. https://www.ipcc.ch/site/assets/uploads/2018/03/TAR-06.pdf.

[35] Stephens, G., Li, J., Wild, M. *et al*. An update on Earth's energy balance in light of the latest global observations. *Nature Geosci* **5**, 691–696 (2012). https://doi.org/10.1038/ngeo1580

The IPCC's "best estimate" of ECS is 3.0°C with a range of 2°C to 5°C (IPCC AR6, Ch. 7).[36] However, some studies (e.g., Lewis & Curry, 2018; Scafetta, 2021; Lewis, 2022; Spencer & Christy, 2023; Lewis, 2025) have estimated ECS to be much lower than the IPCC's best estimate.[37] [38] [39] [40] [41]

Given this spectrum of uncertainty about climate change, the science is far from being settled, especially on the most consequential matters. These disagreements need to be resolved in the scientific literature before governments try to, much less consider, ***intentionally*** altering the atmospheric radiation balance with novel technologies that potentially have a whole host of negative impacts on human health; the ozone layer; and terrestrial, aquatic and marine ecosystems.

The cure might be worse than the disease.

This concludes my testimony.

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[36] Forster, P., T. Storelvmo, K. Armour, W. Collins, J.-L. Dufresne, D. Frame, D.J. Lunt, T. Mauritsen, M.D. Palmer, M. Watanabe, M. Wild, and H. Zhang, 2021: The Earth's Energy Budget, Climate Feedbacks, and Climate Sensitivity. In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 923–1054, doi: 10.1017/9781009157896.009.

[37] Lewis, N., and J. Curry, 2018: The Impact of Recent Forcing and Ocean Heat Uptake Data on Estimates of Climate Sensitivity. *J. Climate*, **31**, 6051–6071, https://doi.org/10.1175/JCLI-D-17-0667.1.

[38] Scafetta, Nicola. 2021. "Testing the CMIP6 GCM Simulations versus Surface Temperature Records from 1980–1990 to 2011–2021: High ECS Is Not Supported" *Climate* 9, no. 11: 161. https://doi.org/10.3390/cli9110161

[39] Lewis, N. Objectively combining climate sensitivity evidence. *Clim Dyn* **60**, 3139–3165 (2023). https://doi.org/10.1007/s00382-022-06468-x

[40] Spencer, R.W., Christy, J.R. Effective climate sensitivity distributions from a 1D model of global ocean and land temperature trends, 1970–2021. *Theor Appl Climatol* **155**, 299–308 (2024). https://doi.org/10.1007/s00704-023-04634-7.

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