DAY ONE PROJECT

Creating a National HVDC Transmission Network

John Tracey

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Summary

The Biden Administration has committed the United States to a 50–52% reduction of greenhouse gas emissions from 2005 levels by 2030 and to net-zero emissions by 2050. To achieve these goals, the U.S. must rapidly increase renewable-energy production while simultaneously building the transmission capacity needed to carry power generated from new renewable sources. Such an investment requires transforming the American electricity grid at a never-before-seen speed and scale; for example, a recent study estimates that a 60% increase in transmission capacity will be required. One way to achieve this ambitious transmission target is to create a national High Voltage Direct Current (HVDC) transmission network overlaid atop the existing alternating current (AC) grid. In addition to advancing America's climate goals, such an effort would spur economic development in rural areas, improve the grid's energy efficiency, and bolster grid stability and security. **This memo proposes several policy options to incentivize private-sector efforts to construct a national HVDC transmission network while avoiding environmental and eminent-domain concerns that have doomed previous HVDC projects. Options range from modest and easily implemented rule changes by federal agencies to more ambitious Congressional actions.**

Challenge and Opportunity

The current American electricity grid resembles the American highway system before the Eisenhower interstate system. Just as paved one or two-lane roads extended to nearly every community by the early 1950s, very few areas are unelectrified today. However, the AC power lines that crisscross the nation today are tangled, congested, and ill-suited to quickly move large amounts of renewable power from energy-producing regions with low demand (such as the Midwest and Southwest) directly to large population centers where demand is highest. Since HVDC transmission lines lose less power than AC lines at distances over 300 miles, HVDC technology is the best candidate to connect the renewable generation required to achieve net-zero emissions by 2050 with power consumers.

There is a dearth of HVDC lines in the United States today, and the few that do exist are scattered across the country and were not designed to facilitate renewable development. In other words, the U.S. is a long way away from the integrated nationwide HVDC network needed to achieve net-zero emissions. Recent attempts by the private sector to begin building long-distance HVDC transmission lines between renewable producing regions and consumers — such as Clean Line Energy's proposal for an aboveground line that would have linked much of the Great Plains to the Southeast — have been unsuccessful due to a host of challenges. These challenges included negotiating leases with thousands of landowners with understandable concerns about how the project could alter their properties, mounting an effective legal defense of the company's use of Section 1222 of the Energy Policy Act of 2005 (which allows developers to assume the federal government's power of eminent domain for large-scale transmission projects if leases cannot be agreed upon), negotiating with many local and state jurisdictions to secure project approval, and maintaining investor confidence throughout the complex and time-consuming permitting and leasing process.

However, a new generation of private developers has proposed an innovative solution that bypasses these challenges: the construction of an underground nationwide HVDC network alongside existing rail corridors. Unlike aboveground transmission built through a mosaic of property owners' holdings, this solution requires negotiation with only the seven major American rail companies, takes advantage of the proximity of these already-disturbed corridors to many areas with high renewable-energy potential (Figure 1), does not add visual pollution to the aboveground landscape, and would likely not require the use of Section 1222 to justify eminent domain.

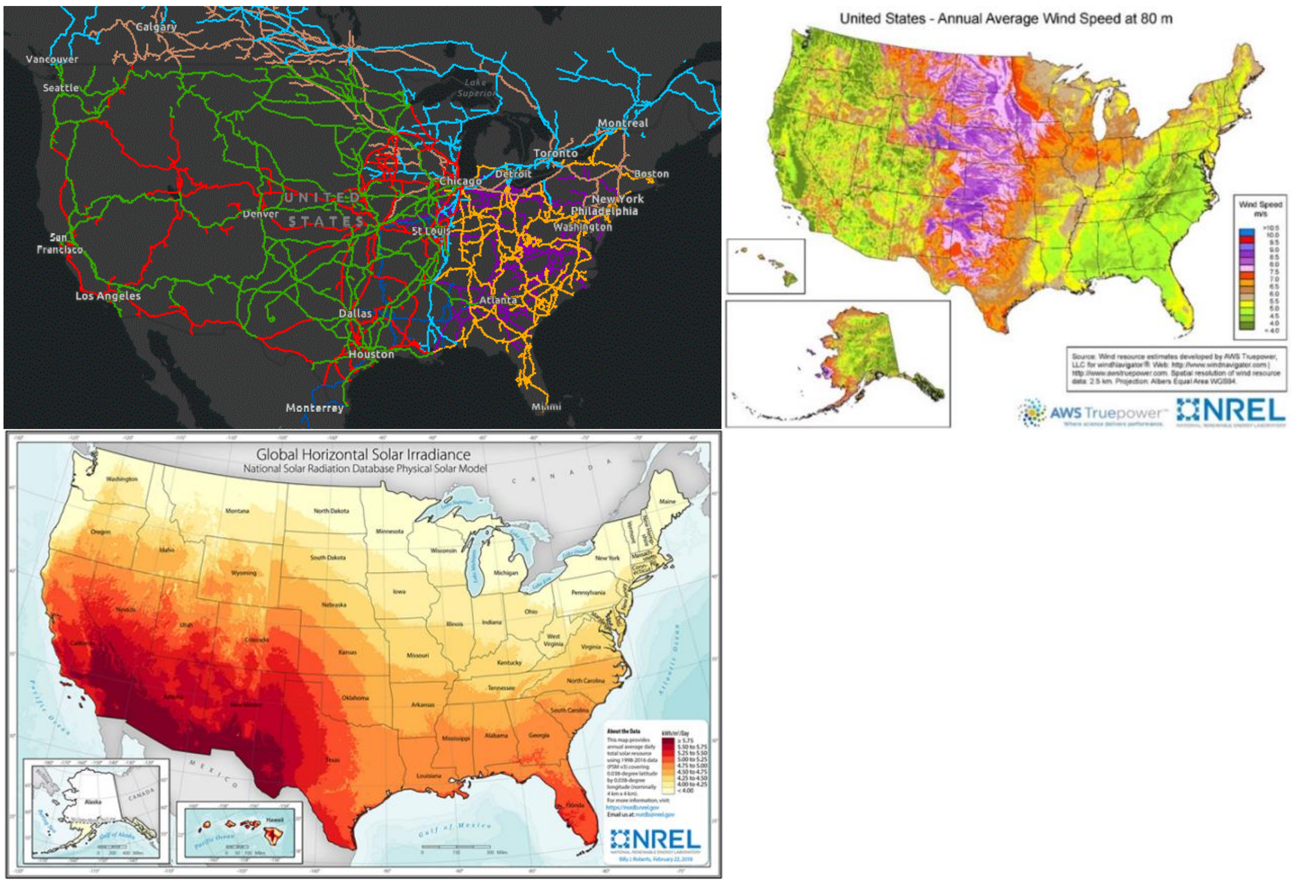

Figure 1: Areas with high potential for wind and solar generation in the Great Plains and Southwest overlap with existing rail routes. Clockwise from left to right, routes of all seven class 1 railways (Source: Federal Railway Administration), heat map of average annual wind speed 80 meters aboveground (an indicator of the potential for wind energy generation; Source: National Renewable Energy Laboratory (NREL)), heat map of global horizontal solar irradiance (an indicator of solar-energy potential; Source: NREL).

In addition to the political considerations discussed above, several recent advances in HVDC technology have driven costs low enough to make HVDC installation cost-competitive with installing high voltage alternating current (HVAC) lines (see FAQ for more details). As a result, incentivizing HVDC makes sense from perspectives beyond addressing climate change. The U.S. electric grid must be modernized to address pressing challenges beyond climate, such as the need for improved grid reliability and stability. Unlike AC transmission, HVDC transmission can maintain consistent power, voltage, and frequency, making it a promising way to support the large-scale incorporation of renewable sources into our nation's energy mix while simultaneously bolstering grid stability and efficiency and spurring rural economic growth.

A nationwide HVDC network would also increase grid stability by connecting the four large interconnections that make up the shared American and Canadian power grid (Figure 2). Currently, the two largest of these interconnections — the Eastern and Western interconnections — manage 700 and 250 GW of electricity respectively. Yet, these interconnections are connected by transfer stations with a capacity of only about 1 GW. A recent study led by NREL researcher Aaron Bloom modeled the economics of building a nationwide HVDC macrogrid that would tie the Eastern and Western interconnections together. The study concluded that such an investment would have a net benefit-to-cost ratio of 1.36 due to the possible ability for a nationwide HVDC grid to (i) shuttle renewable energy across the country as different power sources begin and end generation capabilities each day, and (ii) respond more nimbly to power outages in regions affected by natural disasters.

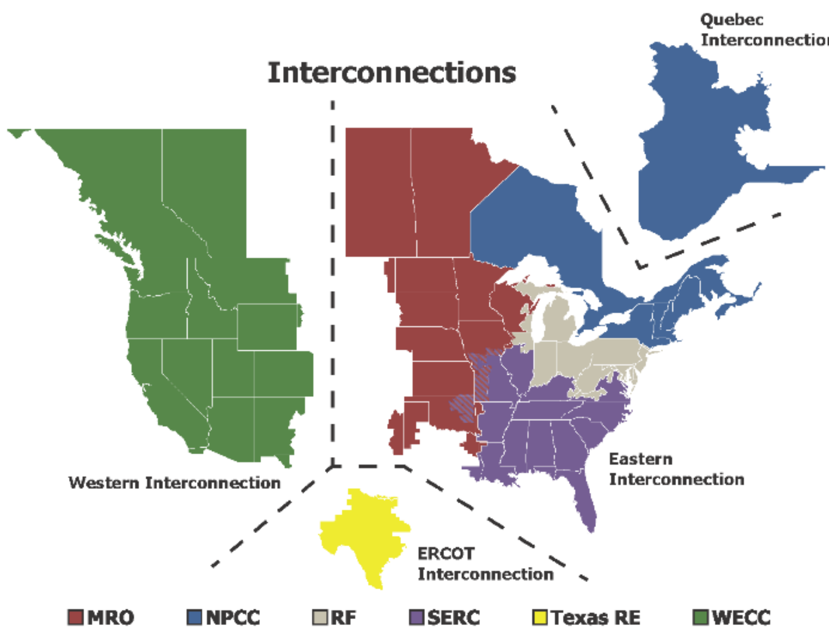

Figure 2: The four interconnections comprising the American and Canadian electricity grid: the Western, Eastern, ERCOT (Texas), and Quebec interconnections. Colors within the Eastern interconnection represent the territories of non-profit entities established to promote and enhance grid reliability within the territories shown on the map. These grid-reliability non-profits should not be confused with

independent system operators (ISOs). (Source: National Electricity Reliability Council (NERC)).

Minneapolis-based Direct Connect, with financial backing from a mixture of American and international investors, has begun the permitting process for SOO Green, the first underground HVDC project co-located with rail lines. SOO Green will run from the Iowa countryside to the Chicago metropolitan area. Although this distance is geographically short, it is significant in terms of the connectivity it will provide. The line will link the Midwest (MISO) and PJM Independent System Operators (ISOs), two of the nine regional bodies that manage much of the United States' grid. The combined territory of the MISO and PJM ISOs stretches from the wind-rich Great Plains to demand centers like Philadelphia, the New York suburbs, and Washington, D.C. Facilitating HVDC transmission in this territory will allow renewable power to be efficiently funneled from regions that produce lots of energy to regions that need it.

By providing a market for wind power in the energy-consuming PJM territory, the SOO Green proposal has already begun to generate interest in expanded renewable development in the wind-rich MISO territory. Direct Connect estimates that the SOO Green HVDC link will spur $1.5 billion of new renewable-energy development, create $2.2 billion of economic output in Iowa and Illinois, and create thousands of construction, operation, and maintenance jobs.

SOO Green's construction specifications, operational plan, and anticipated profit margin are near-ideal for an underground rail co-located HVDC project. The planned route crosses only two states, relies on a low-use railway, lies atop an area with well-characterized geology, and connects the energy-producing Midwest with the energy-consuming Mid-Atlantic. But despite these favorable conditions, SOO Green's attempts to gain approval have been handicapped by outdated utility regulations. Direct Connect's efforts have shown that even proposals with optimal conditions confront difficult permitting pathways. As a result, scaling underground co-located HVDC rapidly enough to achieve the transmission required for net-zero emissions in 2050 requires federal action to make these types of lines a more attractive proposition. The policy options outlined below would encourage other privately backed HVDC projects with the potential to boost rural economies while advancing climate action.

Plan of Action

The following policy recommendations would accelerate the development of a national HVDC network by stimulating privately backed construction of underground HVDC transmission lines located alongside existing rail corridors. Recommendations one and two are easily actionable rule changes that can be enacted by the Federal Energy Regulatory Commission (FERC) under existing authority. Recommendation three proposes a more long-term collaborative effort by the Department of Energy (DOE) and FERC to accelerate nationwide HVDC transmission siting and permitting. Recommendation four is a more ambitious proposal requiring Congressional action.

Recommendation 1. FERC should amend its rules governing how ISOs review new merchant transmission projects.

New merchant transmission projects (transmission lines developed by private companies and not by rate-regulated utilities) and generation projects are often reviewed by ISOs as part of a single interconnection process. In SOO Green's case, the PJM ISO is backlogged in its reviews due to the high volume of new renewable-generation project proposals. This creates a vicious cycle holding back the clean-energy sector: a delayed review of the transmission capabilities required by new renewable-generation projects ultimately chills the market for generation projects as well. FERC should therefore issue a rule that requires PJM and other ISOs to review new renewable generation and new transmission projects on separate tracks.

Recommendation 2. FERC should exempt HVDC transmission projects from external-capacity rules developed for less controllable AC transmission projects.

Under current rules set by the PJM ISO, energy generated outside of the PJM service area can participate in PJM's energy marketplace only if grid operators can directly dispatch that energy. Due to the diffuse nature of renewable-energy generation, it is impossible for PJM operators to dispatch specific renewable-generation projects. In October 2021, SOO Green filed a complaint to FERC alleging that the PJM ISO's external-capacity rules were designed to manage older, less diffuse generation resources — and that these rules need to be updated to allow the technological advantages of HVDC transmission (e.g., the capacity to schedule current flow at pre-agreed upon times and flows along HVDC transmission lines) to benefit PJM customers. FERC should exempt HVDC transmission projects from such rules as ISOs like PJM develop new external-capacity rules better suited to diffuse generation.

Recommendation 3. FERC and DOE should adopt a collaborative strategy to identify mutually agreeable routes for new rail co-located HVDC transmission.

Previous attempts by Congress to establish greater federal power over transmission siting and permitting have revolved around the DOE's authority to designate some counties as National Interest Electric Transmission Corridors (NIETCs). NIETCs are regions that DOE identifies as being particularly prone to grid congestion or transmission-capacity constraints. The creation of NIETCs was authorized by the Federal Power Act (Sec. 216), which also grants FERC the authority to supersede states' permitting and siting decisions if the rejected transmission project is in a NIETC and meets certain conditions (including benefits to consumers (even those in other states), enhancement of energy independence, or if the project is "consistent with the public interest"). This "backstop" authority was created by the Energy Policy Act of 2005 and was recently reformed in 2021's Infrastructure Investment and Jobs Act. Although it is a laudable attempt to spur transmission investment, the revised authority in its current form is unlikely to lead to the sudden acceleration of transmission siting and permitting necessary to achieve the Biden Administration's climate goals. This is because NIETC designation, as well as any FERC action under Section 216, (i) trigger the development of environmental impact statements under the National Environmental Policy Act (NEPA), and (ii) would likely engender strong political opposition by states and landowners whose properties would be part of proposed routes but would not receive any benefits from transmission investments.

Instead of relying solely on this top-down approach, DOE and FERC should adopt a collaborative strategy wherein they work with state governments, the Class 1 railways, utilities, and interested transmission developers to plan and permit future HVDC transmission, including rail co-located projects. This approach, in keeping with the spirit of the Building a Better Grid Initiative, would decrease the possibility of political opposition — especially if rail co-located HVDC is emphasized due to its relatively small number of stakeholders and focus on already disturbed corridors. In addition, if mutually agreed corridors can be negotiated, this collaborative approach would render the lengthy NEPA reviews required for NIETC designation and FERC precedence unnecessary (although NEPA reviews may still be required if federal agencies are involved in the agreed-upon projects in other ways. See FAQ for more information).

Recommendation 4. Create federal tax credits to stimulate domestic manufacturing and construction of HVDC transmission, including HVDC lines along rail corridors.

Congress should create two federal investment tax credits (ITCs) to stimulate a market for American HVDC lines. One tax credit should be directed to American manufacturers of cross-linked polyethylene (XLPE) which serves as the liner for HVDC cables. Such an incentive would help ensure a reliable, predictably priced domestic supply of this essential material. The second tax credit should be directed to HVDC line developers and should be modeled on an existing tax credit authorized by the Energy Policy Act of 2005 (26 U.S.C. § 48) for renewable-generation projects. A tax credit for HVDC line developers was previously introduced by Sen. Martin Heinrich (D-NM) as part of 2019's Electric Power Infrastructure Improvement Act. After stalling in the Senate Finance Committee, this bill was re-introduced in 2021 in both the House and Senate, then incorporated into President Biden's Build Back Better Plan. The HVDC provisions of Build Back Better should be included in House and Senate Democrats' attempts to revive the legislation during the summer of 2022. If negotiations are unsuccessful this summer, the HVDC provisions should be re-introduced via a stand-alone bill framed as a logical expansion of the renewable-generation tax credits enacted with broad bipartisan support in the Energy Policy Act of 2005. This strategy would separate HVDC tax credits from partisan feuding over Build Back Better and would draw greater attention to HVDC's ability to simultaneously foster rural economic development and speed much-needed decarbonization efforts.

Conclusion

A significant increase in transmission capacity is needed to meet the Biden Administration's efforts to achieve net-zero emissions by 2050. Creating a nationwide HVDC transmission network would not only greatly aid the United States' efforts to address climate change — it would also improve grid stability and provide sustained economic development in rural areas across the country. Minneapolis-based Direct Connect's SOO Green project to construct HVDC transmission alongside existing rail corridors is an example of an innovative solution to legitimate stakeholder concerns over environmental impacts and the use of eminent domain —concerns that have plagued previous failed efforts to construct long-distance HVDC transmission. The federal government can stimulate private development of this publicly beneficial infrastructure via simple rule changes at FERC, embracing a collaborative strategy to site and permit new transmission infrastructure, and by passing new HVDC transmission-specific tax credits modeled after existing credits.

Frequently Asked Questions

1. Can you elaborate on the difference between DC and AC? Why did the grid develop as an AC grid?

Direct current (DC) runs continually in a single direction. DC became the standard current for American electricity early in the development of the U.S. grid, due largely to Thomas Edison's endorsement. However, *at that time* DC could not be easily converted to different voltages, making it expensive and difficult to supply power to consumers since different end uses require different voltages. Alternating current (AC), or current that reverses direction at a set frequency, could be converted to different voltages and had its own prominent proponent in Nikola Tesla. Due to the lower costs associated with AC voltage conversion, AC became the technology of choice as city-wide and regional scale power plants and transmission developed in the early 20th century.

2. Can you elaborate on how to decide between HVDC and AC transmission? Under what circumstances should AC and HVDC be used?

In general, AC transmission is more cost-effective for lines that cover short distances, while HVDC transmission is ideal for longer projects. This is mainly due to the physical properties of DC, which reduce power loss when compared to AC transmission over long distances. As a result, DC transmission is ideal for moving renewable energy generated in rural areas to areas of high demand.

An additional factor is the need for HVDC lines to convert to AC at the beginning and end of the line. Due to the history discussed above, most generation and end-use applications respectively generate and require AC power. As a result, the use of HVDC transmission usually involves two converter stations located at either end of the line. The development of voltage source converter (VSC) technology has significantly shrunk the land footprint required for siting converter stations (to as little as ~1 acre) and reduced power loss associated with conversion. While VSC stations are expensive (costing $100 million or more), the expenses of VSC technology begin to be balanced by the savings in efficiency gained through HVDC transmission at distances above 300 miles.

Additional factors that lower the costs for underground rail co-located lines are (i) that America's fracking boom has led to significant technological advances in horizontal drilling, and (ii) the wealth of engineering experience accumulated by co-locating much of America's fiber-optic network alongside roads or railways.

3. Can you quantify the magnitude of the backlog within PJM's approval process?

The current backlog is estimated to be 30 months or more, according to SOO Green's first FERC complaint.

4. Does FERC have the authority to issue rule changes proposed in recommendations one and two of this memo?

Yes, FERC has the authority to issue these proposed rule changes under Section 206 of the Federal Power Act (FPA), which states:

"Whenever the Commission, after a hearing held upon its own motion or upon complaint, shall find that any rate, charges, or classification demanded, observed, charged, or collected by any public utility for any transmission or sale subject to the jurisdiction of the Commission, or that any rule, regulation, practice, or contract affecting such rate, charge, or classification is unjust, unreasonable, unduly discriminatory or preferential, the Commission shall determine the just and reasonable rate, charge, classification, rule, regulation, practice, or contract to be thereafter observed and in force, and shall fix the same by order."

FERC has the authority under Section 206 of the FPA to issue the proposed rule changes because the *classification* of HVDC transmission as generation by ISOs (recommendation 1) and ISO *rules* governing external capacity (recommendation 2) are practices and rules that affect the rates charged by public utilities.

5. What is the permitting framework for large-scale HVDC transmission projects like SOO Green?

Large-scale HVDC transmission projects do not meet the categorical exclusion criteria under the National Environmental Protection Act (NEPA) for transmission construction (<20 miles in length along previously disturbed rights of way; 10 C.F.R. 2021 Appendix B). As a result, environmental impact statements are required to be created by all relevant federal agencies (possibly including the Environmental Protection Agency as well as the Departments of Commerce, Energy, the Interior, Labor, and Transportation). All relevant state and local permitting requirements also apply.

6. Can you elaborate on the collaborative approach that this memo recommends that DOE and FERC adopt? Are there other agencies that should be involved?

To take advantage of the political momentum granted to the newly created DOE Undersecretary of Infrastructure and the relevant expertise within FERC, the new undersecretary, in partnership with FERC's Office of Energy Policy and Innovation

(OEPI), should together lead the collaborative effort by DOE and FERC to work with states, utilities, class 1 railways, and interested transmission developers. To expedite transmission development, efforts to bring representatives from these stakeholders to the table should begin as soon as possible. Once a quorum of interested parties has been established, the Infrastructure Undersecretary and FERC OEPI should facilitate the establishment of regular "transmission summits" to build consensus on possible transmission routes that meet the concerns of all parties.

When necessary, the Undersecretary of Infrastructure and OEPI should also include other relevant agencies and offices in these regularly scheduled planning summits. Possible DOE offices with valuable perspectives are the Office of Clean Energy Demonstrations; the Office of Energy Efficiency, and Renewable Energy; and the Joint Office of Energy and Transportation (co-managed by the DOE and Department of Transportation (DOT)). Possible additional FERC offices include the Office of Energy Market Regulation and the newly created Office of Public Participation. Other relevant agencies include the National Railway Administration within DOT, the Department of Labor, and the Department of the Interior (since lines built in the West are very likely to cross federal land).

Because HVDC transmission is a young industry, coordination among all these agencies and all relevant stakeholders for rail co-located HVDC transmission to proactively develop a clear regulatory framework would greatly aid the maturation of HVDC transmission in America.

7. Given that the 2019 Electric Power Infrastructure Improvement Act stalled in the Senate Finance Committee and that Build Back Better has not yet passed, what is the evidence that tax credits for HVDC transmission infrastructure in a stand-alone bill would have bipartisan support?

Tax credits for HVDC transmission projects and components are a logical extension of existing renewable energy tax credits designed to strengthen the positive economic effects of renewable energy growth in many rural American communities. The original renewable energy tax credits within the Energy Policy Acts of 1992 and 2005 were passed with large, bipartisan margins (93 – 3 and 85 – 12). A focused advocacy effort that unites all stakeholders who stand to benefit from these new proposed tax credits (including rural communities where new renewable generation will be spurred, railroad companies, HVDC developers and manufacturers, urban centers with high renewable demand) would generate the needed bipartisan support.

8. Have other countries built nationwide HVDC transmission networks?

China leads the world in installed point-to-point HVDC transmission. China also recently opened the world's first HVDC grid. Behind China, the European Union has made extensive investments in deploying point-to-point HVDC lines and is planning to develop an integrated European grid by requiring EU members to meet a 15% interconnection target (meaning that each country must be able to send 15% of its electricity to neighbors) by 2030. India, Brazil, Australia, and Singapore have opened or are planning ambitious HVDC projects as well.

About the Author

John Tracey is a Ph.D. student at Princeton University in the Department of Geosciences. His research and professional interests span oceanography, environmental microbiology, biogeochemistry, and environmental policy. Before graduate school, he held an Intramural Research Training Award from the National Institutes of Health to study the biochemistry of the *B. pertussis* (whooping cough) infection mechanism. He has been involved in science policy and education efforts through the Princeton Energy and Climate Scholars and the Federation of American Scientists / National Science Policy Network Early Career Science Policy Accelerator.

About the Day One Project

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