April 2023

INNOVATING

OUT OF THE CLIMATE CRISIS

Reflections and Recommendations for the Clean Energy Transition

ASP

American Security Project

BOARD OF DIRECTORS

The Honorable Gary Hart, Chairman Emeritus
Senator Hart served the State of Colorado in the U.S. Senate and was a member of the Committee on Armed Services during his tenure.

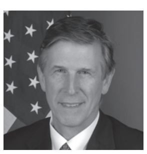
Governor Christine Todd Whitman, Chairperson
Christine Todd Whitman is the President of the Whitman Strategy Group, a consulting firm that specializes in energy and environmental issues.

Lieutenant General Norman Seip, USAF (Ret), President
Lieutenant General Norman R. Seip, USAF (Ret) served in the Air Force for 35 years. His last assignment was Commander of 12th Air Force.

Matthew Bergman
Matthew Bergman is an attorney, philanthropist and entrepreneur based in Seattle. He serves as a Trustee of Reed College on the Board of Visitors of Lewis & Clark Law School.

Ambassador Jeffrey Bleich
The Hon. Jeffery Bleich heads the Global Practice for Munger, Tolles & Olson. He served as the U.S. Ambassador to Australia from 2009 to 2013. He previously served in the Clinton Administration.

Alejandro Brito
Alejandro Brito is President of Brito Development Group (BDG), LLP. In the last twenty years, Mr. Brito has overseen the design, construction, development and management of over 1,500 luxury housing units in Puerto Rico.



The Honorable Donald Beyer
Congressman Donald Beyer is the former United States Ambassador to Switzerland and Liechtenstein, as well as a former Lieutenant Governor and President of the Senate of Virginia.

Brigadier General Stephen A. Cheney, USMC (Ret.), *President Emeritus*
Brigadier General Cheney is the *President Emeritus* of ASP. He has over 30 years of experience as a Marine, and served as ASP's CEO from 2011-2019.

Lieutenant General Daniel Christman, USA (Ret.)
Lieutenant General Daniel Christman is Senior Vice President for International Affairs at the United States Chamber of Commerce.

Robert B. Crowe
Robert B. Crowe has 45 years of experience as an attorney and has an extensive background in the legal and government relations industry.

Lee Cullum
Lee Cullum, at one time a commentator on the PBS NewsHour and "All Things Considered" on NPR, currently contributes to the Dallas Morning News and hosts "CEO."

Nelson W. Cunningham
Nelson Cunningham is Vice Chair and Co-Founder of McLarty Associates, where he was also President until 2022.

Admiral William Fallon, USN (Ret.)
Admiral Fallon has led U.S. and Allied forces and played a leadership role in military and diplomatic matters at the highest levels of the U.S. government.

Scott Gilbert
Scott Gilbert is a Partner of Gilbert LLP and Managing Director of Reneo LLC.

Vice Admiral Lee Gunn, USN (Ret.)
Vice Admiral Gunn is Vice Chairman of the CNA Military Advisory Board, Former Inspector General of the Department of the Navy, and Former President of the Institute of Public Research at the CNA Corporation.

The Honorable Chuck Hagel
Chuck Hagel served as the 24th U.S. Secretary of Defense and served two terms in the United States Senate (1997-2009). He was a senior member of the Senate Foreign Relations; Banking, Housing and Urban Affairs; and Intelligence Committees.

Lieutenant General Claudia Kennedy, USA (Ret.)
Lieutenant General Kennedy was the first woman to achieve the rank of three-star general in the United States Army.

General Lester L. Lyles, USAF (Ret.)
General Lyles retired from the United States Air Force after a distinguished 35 year career. He formerly served as the Chair of USAA.

Dennis Mehiel
Dennis Mehiel is the Principal Shareholder and Chairman of U.S. Corrugated, Inc.

Ed Reilly
Edward Reilly is a Senior Advisor to Dentons, the world's largest law firm.

David Wade
David Wade is a consultant helping global corporations and organizations with strategic advice, public affairs and thought leadership, crisis communications, political intelligence gathering, and federal and legislative strategy.

Climate Security

In this Report

The Biden Administration has made climate action and the clean energy transition national priorities. Galvanized by several federal Executive Orders (E.O.), including E.O. 14008, *Tackling the Climate Crisis at Home and Abroad*; E.O. 14017, *America's Supply Chains*; and E.O. 14057, *Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability*, America's clean energy transition is underway. Climate and energy security remain at the forefront of U.S. foreign policy and national security and both the National Security Strategy (NSS) and National Defense Strategy (NDS) firmly establish energy resilience as key components of U.S. national security. Congress has also passed key pieces of legislation like the Inflation Reduction Act (IRA), the Infrastructure Investments and Jobs Act (IIJA), and the CHIPS and Science Act that have sent important signals to public institutions and private industry to pivot away from fossil fuels to create a new domestic clean energy system.

To better understand the dynamics of the clean energy transition and their relationship to energy security and national security, ASP developed the *Innovating Out of the Climate Crisis* series, which focused on five industry case studies in the energy ecosystem: electrification, hydrogen, carbon emissions, agricultural technology, and hard to abate energy sectors. Through a series of webinars and written publications, ASP identified challenges, opportunities, and potential policy and regulatory remedies that can help implement clean energy policies, foster innovation, and facilitate a durable clean energy transition.

IN BRIEF

- China dominates the clean energy supply chain—from mining and refining rare earth elements and critical minerals, to battery and solar panel production. It has invested nearly four times as much as the U.S. in clean energy. To maintain U.S. economic competitiveness and enhance energy and national security, the U.S. must develop robust research, development, and demonstration (RD&D) funding and programming which foster innovation that can move quickly from lab to market.
- The benefits of transitioning to 100 percent renewable power generation in a clean energy economy could top $1 trillion and have widespread benefits for public health, the environment, and U.S. national security that would far exceed the up-front investments needed to facilitate the transition. By expediting the clean energy transition, the U.S. can reinvigorate its industrial base, enhance its national and energy security, and emerge as the global leader in the clean energy economy.
- IRA, IIJA, CHIPS and Science Act, and the Defense Production Act provided critical funding, signals, and market security for private industry to invest the market capital required conduct critical research, development, and demonstration (RD&D) activities for the clean energy transition.
- Additional actions, such as providing robust RD&D funding, updating transmission permitting standards, and facilitating private sector investments can expedite the clean energy transition and enhance U.S. energy security.

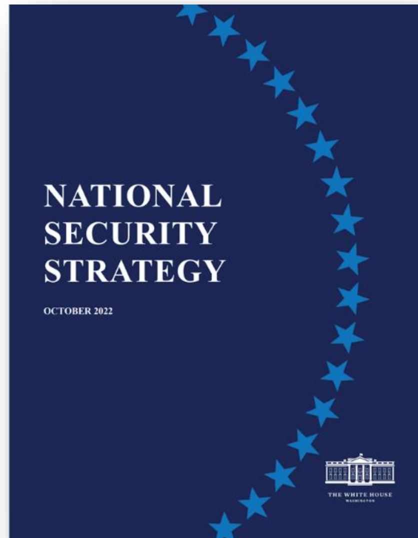
About the Authors

Jessica Olcott Yllemo is the Director, Climate Security Programs at The American Security Project.
Lindsay Iversen is a Senior Adjunct Fellow at The American Security Project.

National Security and the Clean Energy Transition

The U.S. government has linked climate change and national security since the 1990s,[1] acknowledging that the changing climate presents an array of national security risks, ranging from recurring humanitarian emergencies and large-scale migration to political instability and degraded military readiness. Both the 2010 and 2014 Quadrennial Defense Reviews[2] [3] enshrined climate change in defense and security lexicon as a threat multiplier, defining how climate challenges, including energy, pose a risk that compounds existing threats and hazards to create multidimensional security challenges.

In 2021, President Joe Biden went one step further with Executive Order 14008 and put the climate crisis "at the center of U.S. foreign policy and national security."[4] Since then, more than 20 federal agencies have produced climate and sustainability plans that place energy use, security, and sustainability at their core. Both the National Security Strategy (NSS) and National Defense Strategy (NDS), as well as each of the military service branch climate plans, highlight energy resilience as a critical component of national security, lethality, and operational effectiveness.[5]



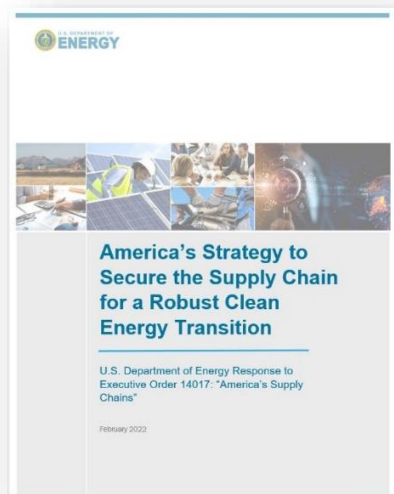
The military is already making concerted efforts to enhance resilience and mitigate greenhouse gas emissions in its day-to-day operations by adopting climate and energy-friendly actions such as non-tactical hybrids and electric vehicles (EVs)[6] and building installation microgrids.[7] The Army alone has 950 renewable energy projects underway today, and 25 installation microgrid projects scoped and planned through 2024—all of which support the Army's goal of building a microgrid at every base by 2035.[8] Likewise, the Department of the Air Force Climate Action Plan lists "Optimiz[ing] Energy Use and Pursu[ing] Alternative Energy Sources" as one of its three priorities necessary to build enduring advantages, reduce costs, and bolster resilience.[9] Moreover, the Department of the Navy's Climate Action 2030 plan points to its long history of transitioning to cleaner forms energy as a central way to limit adverse impacts of climate change, combining innovation with efficiency to meet mission requirements.[10] And the 2021 Department of Defense (DoD) Climate Adaptation Plan highlighted the Army's 2019 innovative "smart energy" technology demonstration during an exercise that has the potential to reduce fuel waste, improve operational effectiveness, and enhance interoperability as a notable accomplishment for the defense enterprise.[11]

The Defense Innovation Unit (DIU) is also spearheading numerous projects focused on energy efficiency and subsequently reducing cost. As Dr. Andrew Higier, DIU's Energy Portfolio Director, recently put it, "DoD views energy resilience as a real-world operational problem that not only needs to be solved but has the potential to save money and lives."[12]

Climate and energy have also become critical issues in U.S. relationships with its two primary strategic competitors: Russia and China. The U.S.-China relationship, perhaps more than any other bilateral relationship, has the capacity to shape the balance of this century. The NDS describes China's efforts to remake the international system to better suit its "authoritarian preferences" as "the most comprehensive and serious challenge to U.S. national security."[13] At the same time, China and the U.S. are, respectively, the first- and second-largest annual greenhouse gas emitters,[14] meaning there is no solution to climate change that does not involve the two countries. Climate advocates in both capitals have historically worked to isolate discussions on climate change from routine diplomatic relations,[15] but climate change and clean energy are increasingly omnipresent.

For the last several decades, China has worked to position itself at the apex of the emerging clean energy economy. Chinese firms already dominate the full battery supply chain, including 90 percent of mining and refining essential rare earth elements,[16] most of the battery manufacturing and recycling, and it will control some 65 percent of the lithium-ion battery market by 2025. Likewise, Chinese firms control more than 80 percent of the solar panel manufacturing process, from components to finished products, and are projected to control more than 95 percent in the coming years.[17] This level of market concentration—especially in the critical minerals industry—is a significant security risk for the U.S. According to the U.S. intelligence community, Beijing intends to "increase global supply chain dependencies on China, with an aim of controlling key supply chains and being able to use those supply chains to threaten and cut off foreign countries during a crisis."

Unlike China, which has focused its efforts on dominating the energy supplies of the future, Russia's energy power remains in legacy fuels, particularly oil and gas. Prior to its 2022 invasion of Ukraine, Russia accounted for more than 10 percent of global oil exports, much of which went to Europe.[18] It was also the world's largest exporter of natural gas and a dominant supplier to the European Union; prior to the war, it accounted for 45 percent of European gas imports.[19] Though Russia had been a reliable supplier through previous relationship hiccups, American policymakers regularly warned their European counterparts about the dangers of overreliance on a single supplier. It was only in 2022, as Russia throttled back gas deliveries[20] and Europe faced blistering political pressure to cut oil imports in response to Russia's invasion of Ukraine,[21] that the national security risks burst from the theoretical to the real.



U.S. officials, alert to the risks of politically motivated disruptions in both current and future energy technologies from these two strategic competitors, have been studying ways to diversify American energy supply chains to enhance national and energy security. In response to E.O. 14017, *America's Supply Chains*, the Department of Energy (DOE) published *America's Strategy to Secure the Supply Chain for a Robust Clean Energy Transition.*[22] Released, coincidentally, on the same day that Russia launched its full-scale invasion of Ukraine, the strategy assesses the current domestic energy sector industrial base and the steps the United States can take to maximize opportunities across the sector. These include developing new domestic raw material resources; developing manufacturing capacity; forming reliable foreign supply chains; increasing clean energy adoption; and building a clean energy workforce.

As the DOE strategy implies, the clean energy transition will have profound impacts on the economy and U.S. economic competitiveness. Private sector clean energy investment broke records in 2022, with investments in the U.S. alone rising 11 percent to $141 billion.[23] Federal policy will bolster this trend; according to one independent analysis, provisions in the IRA and IIJA can generate an additional 900,000 net jobs by 2035 and, with additional federal policies and domestic clean energy manufacturing technologies, could provide up to an additional net 5.7 million jobs under a net-zero emissions pathway.[24]

In short, by expediting the clean energy transition, the U.S. can reinvigorate its industrial base, enhance its national and energy security, and emerge as the global leader in the clean energy economy.

Key Federal Legislation and Activities

Acknowledging the central role energy and climate play in national security, the Biden Administration issued several determinations that are guiding the U.S. clean energy transition. As noted above, E.O. 14008 put the climate crisis "at the center of U.S. foreign policy and national security,"[25] ensuring that it would be a prominent consideration in national security decision-making. E.O. 14017 ordered a federal review of domestic manufacturing and energy supply chains, with a view to making critical supply chains resilient, competitive, and aligned as much as possible with allies and partners.[26] And E.O. 14057 leverages the government's purchasing power to accelerate a full transition to 100% carbon free electricity.[27] In addition, in 2022 the Biden administration invoked the Defense Production Act (DPA) to accelerate domestic production in five key energy areas, (1) solar; (2) transformers and electric grid components; (3) heat pumps; (4) insulation; and (5) electrolyzers, fuel cells, and platinum group metals, to stimulate the domestic energy enterprise.[28]

Congress also passed three major federal laws that provide more than $900 billion in funding for clean energy related programs, projects, infrastructure, and research. These laws provide critical financial resources and incentives to foster innovation and widespread adoption of clean energy technology. Speaking at an ASP webinar, Jeremy Harrell, Chief Strategy Officer at ClearPath reflected that, "In the last five years, we have had more attention paid to supply chains and heavy industry decarbonization than ever before. It's the first time we've seen this influx of [federal] policies targeting industries from a climate perspective. From the Energy Act of 2020, Infrastructure Investments and Jobs Act (IIJA), CHIPS and Science Act, and the Inflation Reduction Act (IRA)—the federal support for research, development, and demonstration (RD&D), funding, and incentives will allow us to scale innovative technologies like carbon capture.[29]

Collectively, these federal actions help remedy the "green premium" that both public and private energy stakeholders might have otherwise faced in adopting new, lower-carbon, and climate-friendly technologies and products.

Infrastructure Investment and Jobs Act (IIJA)

In November 2021, Congress passed the IIJA, a bipartisan bill that provides $550 billion in spending and investments for domestic infrastructure across the transportation, power, industry, and building sectors, as well as for broadband internet access and clean drinking water.[30,31] IIJA has several notable clean energy investments, including:

- Major new funding for clean transportation, including $39 billion to repair, upgrade, and enhance transit infrastructure and facilities, $7.5 billion to expand electric vehicle charging infrastructure,[32] and $5 billion to facilitate the adoption and deployment of electric school bus fleets;[33]
- More than $65 billion in clean energy related transmission line upgrades and U.S. electric grid investments;[34]
- Creation of the Grid Deployment Authority to invest in demonstration projects and next generation technology research hubs, as well as the Building a Better Grid Initiative to develop and deploy high-capacity electricity transmission lines;[35]
- $12 billion for carbon capture and storage (CCS) and transportation projects, including $2.1 billion in direct funding (which translates to $20 billion in lending authority) for DOE's Loan Program's Office to finance carbon transportation pipelines and other infrastructure;

- $6.5 billion for DOE's Office of Fossil Energy and Carbon Management (FECM), with $3.5 billion supporting regional direct air capture hubs;
- $2.5 billion in carbon capture demonstration projects and pilots; and
- New resources to ensure that physical and cyber infrastructure is resilient to a more volatile climate; clean up abandoned industrial and energy sites; and secure critical supply chains.[36]

CHIPS and Science Act

Also on a bipartisan basis, in 2022 Congress passed the CHIPS and Science Act, an industrial policy bill designed to shore up American innovation and manufacturing in critical computing technologies. The bill has received less attention than the IIJA and the Inflation Reduction Act, but it has several important provisions that are beneficial to lowering emissions, including boosting the domestic semiconductor industry. Since semiconductors are essential for several clean energy systems, including solar and wind, a robust domestic industry will help foster economic competitiveness, energy security, and domestic resilience.[37] The bill provided $280 billion for research and development (R&D) in zero-carbon technologies, and established a Directorate for Technology, Innovation, and Partnerships (TIP) at the National Science Foundation to advance U.S. competitiveness through investments and developments of key technologies.[38] So far, Congress has appropriated $1.8 billion to the National Science Foundation and the National Institute of Standards and Technology to begin implementation.[39]

Inflation Reduction Act (IRA)

Congress passed the landmark IRA in August 2022, which has profound implications for clean energy investment and innovation. The IRA offers direct federal funding as well as tax credits and other incentives to spur private sector investment in clean energy, to the tune of approximately $369 billion.[40] The IRA provides funding for electrification, energy efficiency initiatives, EVs and EV infrastructure, and state-level climate plans.[41] It includes clean energy tax credits in several key areas, including clean hydrogen production, renewable power generation, and eligible advanced manufacturing processes, including solar, wind, battery components, and critical minerals, as well as nuclear energy. It provides approximately $500 million for enhanced use of the Defense Production Act, specifically for critical mineral processing and heat pumps.[42] It dramatically expands the existing tax credits for both point-source and direct air capture,[43] as well as tax credits for carbon management, low carbon construction materials, and forest management. Furthermore, it addresses a known development bottleneck by dedicating several critical funding lines to expediting the permitting process, including grants for the siting and permitting of interstate transmission projects and funding for staff and resources to expedite environmental reviews.[44]

These provisions and more, which are expanded on in the sections below, are a watershed for U.S. climate policy and clean energy innovation. According to the Rhodium Group, "these [IRA] incentives…provide a decade of policy certainty for the clean energy industry to scale up… and help reduce the green premium… potentially creating the market conditions to expand these nascent industries to the level needed to maintain momentum on decarbonization."[45] In just the first six months after the IRA was signed, an independent analysis shows more than 100,000 "green jobs" were created in the U.S.[46] Many of those jobs are going to priority energy communities[47] that are transitioning from fossil fuel-driven heavy manufacturing to clean industries. Not only are these efforts reinvigorating former steel and coal regions, but they are also creating a robust workforce that can fill critical skill gaps in the energy industry. Since approximately 50 percent of the current energy utility workforce is at or above retirement age, so that investment is both timely and essential.[48]

Clean Energy Innovation Areas of Focus

Global net greenhouse gas emissions grew more than 10 percent from 2010 to 2019. Nearly 80 percent of these emissions came from industry, energy generation, transportation, and buildings, where increases in global production have outpaced improvements in energy efficiency. Likewise, agriculture, forestry, and other land uses also account for a significant proportion of emissions.[49] Achieving the world's climate goals will require dramatic emissions cuts across all these sectors—a monumental task in which innovation will be central.

The International Energy Association projects that almost half of global emissions reductions by 2050 will come from technologies that exist only as prototypes or demonstration projects today.[50] As such, ASP's *Innovating Out of the Climate Crisis* series focused on five industries in the energy ecosystem where technology is advancing rapidly and recent federal actions are catalyzing complex change: electrification, hydrogen, carbon emissions, agricultural technology, and hard to abate energy sectors. Through a series of webinars and written publications, ASP identified challenges and opportunities, as well as potential policy and regulatory remedies that can help foster innovation and facilitate a robust clean energy transition.

Agricultural Technology

Agriculture, food, and related industries play a significant role in the U.S. economy. Farmers and ranchers are stewards of more than 900 million acres of land, and the sector supports some 21 million jobs and $1 trillion in U.S. gross domestic product (GDP).[51] However, agriculture is also responsible for more than 10 percent of U.S. greenhouse gas emissions.[52] Unlike most industries, carbon dioxide is not the primary concern in farming. Methane, predominately from livestock digestion, and nitrous oxide, mainly from manure and fertilizer breakdown in the soil, are the sector's primary sources of emissions. These are extremely potent, with global warming effects many times that of CO_2.[53] Moreover, in the coming decades, climate change will make farmers' jobs more difficult than ever, as rising temperatures, unpredictable rainfall, and spreading pests take their toll on production. Climate change could reduce profits for critical U.S. crops like corn, soy, wheat, and cotton by more than a third in the next 50 years.[54] Innovative technologies and farming practices, however, may not only be able to help farmers adapt to climate change but could also one day turn farms into net carbon sinks.

Because agriculture's greenhouse gas emissions stem from interactions between human and natural systems, they present unique innovation challenges. Today, scientists are developing new fertilizer formulations that can reduce chemical and biological interactions in the soil that degrade fertilizer into nitrous oxide and may even help improve crop yields. Researchers are also working on specialized animal feeds that can reduce the amount of methane produced during digestion.[55]

Innovation can affect more than just farm inputs; agricultural practices are also ripe for data-driven change. Precision agriculture techniques,[56] for example, help farmers deliver only the fertilizer, pesticides, and other inputs they need on any given fraction of their land. Since most agricultural chemicals are made with fossil fuel feedstocks, widespread adoption of precision techniques could cut the industry's emissions by as much as 27 million metric tons of CO_2 equivalent per year by 2030.[57] Meanwhile, soil management techniques that reduce soil disturbance, increase the variety of plants on the land, and ensure that the earth is covered for more of the year, can improve water retention and soil microbial health, and may increase carbon sequestration.[58]

Additionally, managing livestock grazing more intensively, so they are moved more often to allow soils and pastures to recover, may both sequester more carbon and improve biodiversity.[59]

Adoption of these tools and techniques is slow, however. Advanced fertilizers are currently more expensive than standard products, limiting their appeal to price-sensitive growers. Likewise, most cattle, sheep, and other ruminants spend most of their lives on pasture, which makes methane-reducing feeds difficult to deliver at scale. And though precision and regenerative agricultural practices generally require fewer inputs, they often nonetheless demand additional equipment, labor, and knowledge—all barriers to adoption for many farmers.

Developing and deploying innovative agricultural technologies is an immense challenge that public policy can help deliver, but in recent decades, public investment has been going in the wrong direction. Over the last 20 years, public spending on research and development in agriculture has declined by nearly 30 percent, even as climate change has put added pressure on the sector.[60] And, while the U.S. Department of Agriculture (USDA) dedicates funding to improving on-farm conservation techniques, including better soil and grazing management, those programs tend to be heavily oversubscribed.[61]

The IRA took major steps forward, dedicating approximately $20 billion in funding for climate-smart agriculture through several USDA programs that will provide "direct climate mitigation benefits… [including] technical assistance for producers to advance conservation."[62] And, in 2022, USDA launched the Partnerships for Climate-Smart Commodities, a $3 billion program intended to help growers develop and market climate-friendly crops, laying the groundwork for an expanded market for those types of commodities.[63] The ongoing 2023 Farm Bill[64] negotiations in Congress will provide another opportunity for innovations in the sector; climate-related programs are expected to be a main area of focus in Congressional debates.

"Cover Crops, "Cereal rye cover crops on Steve Berger farm near Wellman, IA in Washington County, Photo by University of Arkansas Agricultural Experiment, CC By 2.0

Carbon Emissions

The Intergovernmental Panel on Climate Change (IPCC) estimates that, to limit global warming to 1.5°C, the world will need to rely on carbon capture and removal technologies[65] to mitigate carbon emissions from both existing facilities that have not reached their natural lifespan and to capture process carbon emissions like those from steel and cement.

Carbon capture is not a new technology; a small number of systems have been in operation for decades, with most of the captured carbon being used to boost oil production from dwindling wells.[66] There are several approaches to carbon management. The two most common are carbon capture and storage (CCS) and carbon capture and utilization (CCU). In both approaches, carbon capture devices are attached to industrial smokestacks to filter out carbon before it reaches the atmosphere; the difference between them is what happens after the carbon is captured. CCS systems store carbon permanently underground, while CCU systems utilize captured carbon by turning it into fuels and/or chemicals.[67] Direct air capture (DAC) systems, meanwhile, offer a third approach to carbon management. These devices pull CO_2 from the ambient atmosphere, and the carbon is then stored underground or utilized. They have the virtue of being deployable anywhere, not just at specific carbon sources, but the technical challenge of capturing diffuse atmospheric carbon is a daunting one.

The cost of building and operating the systems, however, has hindered their widespread development; only twenty or so CCUS commercial operations are in operation today.[68] Even as zero-carbon energy generation and transmission infrastructure comes online in the years ahead, there are still countless energy and industrial facilities across the country and around the world that are decades away from reaching their intended lifespan. Shutting down these facilities early would result in trillions of dollars in stranded assets—according to one study, an early shutdown of coal-fired power generation alone would cost up to $2.3 trillion—and replacing them with new energy and industrial sources even more.[69]

Policymakers are working to improve the efficiency and cost-effectiveness of the technology, most notably through a multi-billion dollar expansion in R&D funding in the IIJA.[70] And, to boost commercial deployment, the IRA has enhanced the 45Q tax provision (the main tax credit for carbon capture technologies) to both expand eligibility and increase payments to companies that are able to demonstrate that they've safely sequestered carbon dioxide or utilized it in a long term product.[71] Jack Andreasen, Manager, Carbon Management, U.S. Policy and Advocacy at Breakthrough Energy, pointed to the IRA's tax credits as key to getting CCS technology off the ground and into the market. "The federal government's investment [in this sector] is driving down total systems cost. Whether it's in storage, transportation, or feed stocks, there are a number of investments occurring across the system that are making this technology more deployable."[72]

Other carbon management technologies are at an earlier stage of technical development. Direct air capture systems, which filter carbon dioxide at very low concentrations from the air, can cost upwards of $300 per ton of carbon captured and are themselves energy-intensive to run. Nature-based solutions, such as afforestation and soil carbon sequestration, may enable people to harness natural processes to store carbon, but questions remain about how to measure the amount of carbon captured and to ensure it remains stored for the long term.[73] In 2021, DOE launched a decade-long program called the Carbon Negative Earthshot to answer these questions and more. Its goal is to further the development of carbon removal technologies that remove and store carbon from the atmosphere at gigaton scales, for less than $100 per ton.[74]

Private industry has also recognized the enormous potential in the carbon industry, and some are increasingly willing to make the large capital investments necessary to deploy carbon management technologies. The First Movers Coalition, a 65-company group, has pledged more than $12 billion to help facilitate and scale new carbon removal technologies.[75] Similarly, major technology players like Stripe, Meta, and Alphabet, are collaborating on a multi-million-dollar advanced market commitment to stimulate deployment of carbon removal technologies.[76]

Electrification


Power Transmission Lines, Photo by Oran Viriyincy, CC By SA 2.0

One of the keys to achieving the U.S. goal of economy-wide net zero emissions by 2050 is electrifying as much of the economy as possible. This includes actions such as transitioning the consumer and commercial vehicle fleets to EVs, replacing gas-fired stoves, water heaters, and furnaces with electric models and heat pumps, and meeting as many industrial processes needs as possible with electrically generated heat. To meet this increased electricity demand, U.S. power generation will need to grow to up to four times today's levels, all from renewable or zero-carbon sources, while simultaneously transitioning the current fleet of fossil fuel-fired power plants to net zero sources.[77]

Unlike fossil fuels, which can generate power continuously, renewable sources like wind and solar fluctuate depending on weather or the time of day. And, while fossil fuels can be moved from where they are extracted to where they are needed, renewable sources must be converted immediately to electricity and transported by wire. To make the most of this resource, renewable energy must be moved through time (with storage) or through space (with transmission).[78]

Innovation in the electricity sector is driving progress on both fronts. The cost of generating renewable energy has dropped significantly over the last decade. Globally, the price of new, utility-scale solar photovoltaic generation fell by 88 percent from 2010-2019, while onshore wind fell by some 68 percent and offshore wind by 60 percent, making these power sources cost-competitive with fossil fuels.[79]

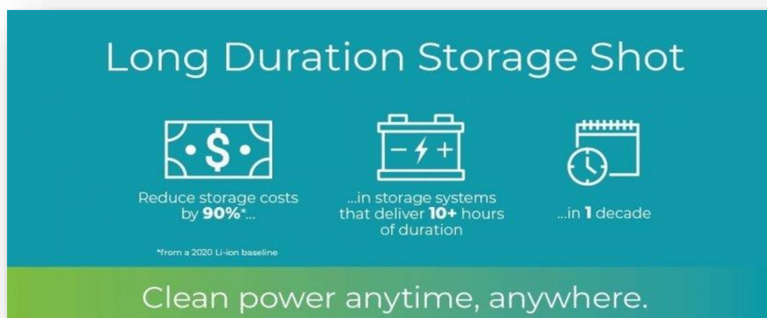
Technological innovations like smart grids can help balance supply across a network,[80] making it better able to handle variable renewable energy sources, and advanced meters can give end-users insight into their power consumption and help smooth out demand.[81] But it is in the policy sphere where innovation is most needed. Today, the U.S. electricity grid is fragmented, with few interconnections between different regions. Yet, most of the renewable energy generation potential in the United States is far from the urban and suburban metros where most energy is consumed.[82] Integrating these grids into a single, national system and enabling them to share energy across distance could allow the U.S. to reduce its carbon emissions by 42 percent.[83]

To bring that energy to consumers, total grid capacity will need to grow by as much as three times by 2035, requiring up to 10,000 miles of new, high-capacity lines each year beginning in 2026.[84] Yet, today, prolonged siting and planning negotiations among local, state, and federal officials mean that it takes over ten years to build power lines across state or regional borders. Some 750 gigawatts of proposed renewable energy projects are currently waiting in these years-long lines to be built.[85]

On the storage side, the cost of lithium-ion batteries (the most common type of battery for everything from iPhones and EVs to short-term, utility-scale storage) has plummeted by nearly 90 percent from 2010-2019, thanks to improvements in design, chemistry, and manufacturing efficiency.[86] At durations of more than a few hours, however, lithium-ion batteries become too expensive to serve as long-term storage; the cost of building and maintaining them cannot be recouped on the rare occasions where they would be called into service.[87]

As such, DOE is working to develop long-term storage technologies at a maximum of one-tenth the cost of lithium-ion batteries. These include flow batteries, which can be charged and discharged (or cycled) many thousands of times without losing battery capacity, making them a better long-term investment than shorter-lived lithium-ion batteries.[88] Mechanical batteries, using gravity[89] or compressed air,[90] are also under development. Pumped hydropower, where renewable energy is used to fill a reservoir that can later be drained and passed through turbines to generate power, is one form of a gravity-based mechanical battery. It is currently the most common form of long-term energy storage, accounting for some 90 percent of deployed capacity, but its future scope is limited by the need for appropriate topography and ample water.[91] Scientists are also developing new forms of chemical storage, transforming renewable energy into hydrogen or ammonia, which can be used as fuels. Venkat Srinivasan, Director of the Argonne Collaborative Center for Energy Storage Science (ACCESS), reflected that researchers are engaged in a "horse race—a race in which there is likely to be more than one winner."[92]

New federal policies are working to increase clean power generation, transmission, and storage. The IRA extends and expands federal tax credits for clean energy generation[93] to increase clean energy capacity within the electricity system and offers incentives for adopting electric vehicles[94] and electric or energy efficient home appliances.[95] It also includes a production credit for clean energy generation technologies like battery cells, solar panels, and wind turbines that could add up to some $400 billion in support for the industry over the coming decade.[96] To handle this new supply and demand, in early 2022, DOE launched the Building a Better Grid initiative, which includes some $20 billion in financing to improve grid capacity, optimize network organization, and more, and empowers DOE to coordinate planning and permitting for the grid of the future.[97] To help ameliorate permitting delays, the IIJA also clarifies the Federal Energy Regulatory Commission's (FERC) ability to site power lines, though this power is yet untested.[98]



Batteries and storage technologies received significant new funding through the IIJA as well, including more than $500 million for energy storage demonstration projects, $6 billion for advanced battery research and supply chain investments, and $3 billion for battery material processing demonstration facilities.[99] DOE is also dedicating an Energy Earthshot to long duration storage, aiming to reduce storage costs by 90 percent (relative to 2020 lithium-ion batteries) over the next decade for systems that can deliver at least ten hours of power. Research funding will go toward a variety of storage technologies, including mechanical, electrochemical, thermal, or some combination thereof.[100] For already-mature storage technologies, the IRA offers new tax incentives for deployment.[101]

Hard to Abate Energy Sectors

Heavy industries like steel and cement manufacturing, along with heavy transportation like shipping and aviation, are notoriously difficult to decarbonize. Making steel and cement, for example, requires very high temperatures—in excess of 1000°C —that cannot be generated efficiently through electricity. The chemical process of making both materials, moreover, generates CO_2 over and above the carbon emitted in generating all that heat. And today's batteries are not yet sufficiently energy-dense to enable heavy transportation to be electrified.[102] This is not a trivial problem; cement and steel are some of the most heavily used materials on the planet, and international shipping underpins the modern economy. Together, these industries make up approximately 30 percent of global carbon emissions.[103]

Cement Factory, Photo by Astrid Westvang, CC By-NC-ND-2.0

Innovation in these foundational industries presents both business and technical challenges. As Dr. Ed Rightor, Director of the Center for Clean Energy Innovation at the Information Technology and Innovation Foundation commented, "…these sectors are energy intensive and face fierce competition. They are mature industries their products are intertwined with complex supply chains, so making changes is difficult."[104] Nonetheless, the DOE's Industrial Carbonization Roadmap[105] identifies four pillars that can make carbon emissions reductions in these sectors possible: (1) energy efficiency; (2) electrification; (3); low-carbon fuels and feedstocks; and (4) carbon capture, utilization, and storage (CCUS). And, despite the business challenges, industry has taken some initial steps along that road with new materials, processes, and fuels. Cement manufacturers, for example, are exploring alternate formulas to minimize the use of clinker (the most energy-intensive ingredient), and engineers are designing buildings and structures using less steel. Carbon capture technologies (though still in their infancy in industrial settings) can mitigate both heat and process emissions from steel and cement manufacturing; some captured CO_2 is even being utilized in concrete to make the material stronger. Hydrogen and ammonia—especially when generated through green processes—can be burned to generate zero-carbon industrial heat and used as transportation fuel.[106] The International Energy Agency (IEA) estimates that hydrogen and ammonia will play increasingly central roles in fueling trucking and shipping in the coming decades.[107]

Nonetheless, many of the technologies in this space are still in the innovation stage. Some 96 percent of the technologies needed to decarbonize aviation, for example, are still in the prototype or demonstration phase,[108] as are 62 percent of those needed to decarbonize steel.[109] To help move the industry forward, the IIJA included substantial new funding to support relevant research and development initiatives, including $8 billion for a nationwide system of hydrogen industries (see Hydrogen below) and $1 billion for carbon capture demonstration projects on heavy industrial facilities.[110]

Once they are ready to deploy, new policies will be needed to get these technologies into the market as quickly as possible. The IRA offers tax credits to companies that install carbon capture technologies and utilize captured carbon for other purposes,[111] as well as to firms using sustainable fuels.[112] Federal policymakers are also leveraging the power of the private sector to drive demand for low-carbon processes in this sector. The First Movers Coalition, brought together by the U.S. Department of State and the World Economic Forum, has secured commitments from 65 global corporations to purchase near-zero emission cement, steel, and other hard to decarbonize products. These forward purchase commitments are intended to catalyze markets and drive down prices in the coming decades.[113]

Hydrogen

Hydrogen, the most plentiful element in the universe, may also be in the early stages of becoming one of humanity's most common energy sources. It can burn hot enough to make steel and cement, and long enough to support long-haul trucking and shipping. [114] It can also be transported over distances in pipelines and stored until it's needed, so it can be a backup fuel for variable electricity sources like wind and solar. And it can do all that while generating no carbon emissions at the point of use. Achieving this, however, will require new ways of manufacturing hydrogen and new markets for using it. [115]

Today, the U.S. makes about 10 million metric tons of hydrogen per year, mainly as a chemical feedstock for fertilizer and for use in oil refining.[116] Virtually all this hydrogen—about 95 percent of it—is made with fossil fuels, sometimes referred to as gray hydrogen. It is primarily made by breaking down natural gas with high-temperature steam,[117] a carbon-intensive process that generates the equivalent of about 10kg of CO_2 for every 1kg of hydrogen it produces.[118]

One approach to making net-zero hydrogen is to equip hydrogen manufacturing facilities with carbon capture devices. Though fossil fuels would still be used as a feedstock for the process and to generate the necessary heat, the resulting CO_2 could be captured at the smokestack and stored or used. The resulting hydrogen—sometimes referred to as blue hydrogen—could therefore be a net zero fuel. A second approach to manufacturing hydrogen removes fossil fuels from the equation entirely. In a process known as electrolysis, electricity is used to split water into hydrogen and oxygen; if that electricity comes from renewable sources, the process is entirely carbon-free.[119] The resulting hydrogen is sometimes referred to as green hydrogen to reflect this no-carbon pedigree.

The biggest challenge for hydrogen is that it remains prohibitively expensive. Incorporating carbon capture systems into hydrogen manufacturing, for example, would cost up to $80 per ton of carbon captured[120]—a hefty additional cost for producers. And generating hydrogen through electrolysis will require vast amounts of renewable electricity. Meeting just current global hydrogen demand with green hydrogen would require 3,600 terawatt hours of renewable power annually—more than is produced today in the entire European Union.[121]

In the last few years, the federal government has made unprecedented investments to develop and scale the hydrogen economy. The IIJA alone allocated $9.5 billion to new hydrogen projects. The majority of the funding—$8 billion—will support up to ten new domestic Hydrogen Hubs: clusters of researchers, producers, and consumers of hydrogen produced in a variety of methods, all over the country, that can serve as commercial centers for the nascent industry.[122] The IIJA also allocated $1 billion to reduce the cost of green hydrogen, which today costs about $5/kilogram (kg)[123]—more than five times the cost of conventionally produced gray hydrogen.[124] Through its Hydrogen Earthshot, a research, development, and commercialization program, DOE is also working to bring the cost of green hydrogen down to $1/kg in just ten years.[125]

Provisions in the IRA, meanwhile, may make hydrogen cost-competitive much sooner. It extended an existing tax credit for hydrogen production, and crucially, established a sliding credit scale based on the carbon intensity of production. At the moment, only green hydrogen has a low enough carbon intensity to claim the full $3/kg credit, but some blue systems may be efficient enough to claim partial credit.[126] Speaking at an ASP webinar, the Clean Air Task Force's Emily Kent said that this "pay for performance" approach was a "beneficial direction for those policies to go," as carbon intensity thresholds can be met by most production methods depending on choices made at the project level.[127] Once made, all this hydrogen will need a place to go. Per Kent, industries such as steelmaking, shipping, and aviation need anywhere from a few years to a few decades to get market ready. Giving would-be hydrogen producers confidence that there will be consumers down the line could reassure investors and bolster overall market development.

Reflections and Recommendations

The recent federal support for the clean energy value chain is unprecedented and has undoubtedly helped provide the necessary signals to public and private stakeholders that the clean energy transition is underway. These steps, however, are just the first of a marathon, not a sprint, and to achieve their goals, they must be sustained and built upon. In the years to come, Congress and the relevant Executive agencies should consider the following steps to institutionalize continual progress on the clean energy transition and disseminate that progress globally.

Transmission Permitting

Throughout the course of ASP's *Innovating Out of the Climate Crisis* programming, permitting emerged as a critical area in need of policy attention and reform. Specifically, slow construction of new electric transmission lines due to permitting delays is causing "interconnection queues" for a growing number of clean energy projects.[128] Transmission siting and permitting can take ten or more years to get approval from local, state, interstate, and federal authorities due to a complex regulatory framework that too often fails to strike the right balance between reasonable environmental and community reviews and the need for clean energy infrastructure development.[129]

Simplifying and streamlining the permitting process for renewable energy and clean energy projects is essential to the clean energy transition, as well as the success of legislation already passed by Congress. According to a Princeton University Zero Lab study, if the current rate of transmission line construction continues, approximately 80 percent of the emissions cuts and benefits from the IRA will not come to fruition.[130]

The sometimes cripplingly slow integration of renewable and other clean energy projects could be one of the most prohibitive hurdles in the clean energy transition. Speaking at an ASP webinar in April 2023, Jeremy Harrell, Chief Strategy Officer at ClearPath, remarked that the next five to ten years are a "critical moment" for clean energy deployment. Ensuring that projects are environmentally sound is important, he argued, but "what would be the worst thing possible is that we get to a point where the technology is ready to be commercialized and scale up and we've missed the opportunity to deploy them because of unnecessary regulation."[131] Though there is surprisingly broad agreement in Congress that it is too difficult to build new energy infrastructure, it has not yet been able to reach agreement on just which regulations are unnecessary.[132]

In 2022, DOE launched a National Transmission Needs Study to provide more clarity on the capacity constraints and congestion in the U.S. electric transmission grid.[133] The study will examine both historic transmission issues, as well as future anticipated challenges. Similarly, the Biden Administration issued a Permitting Action Plan to implement the permit reform provisions from the IIJA.[134] While these are important steps, Congress should work to agree on an updated, expedited regulatory process to ensure existing laws see their full benefit.

> "If electricity transmission cannot be expanded fast enough, power sector emissions and associated pollution and public health impacts could increase significantly as gas and coal-fired power plants produce more to meet growing demand from EVs and other electrification."
>
> Princeton University Zero Lab
> Electricity Transmission is Key to Unlock the Full Potential of the Inflation Reduction Act, 2022

Additional RD&D Funding

The efficiency and affordability of myriad technologies, from electric vehicles to renewable energy, have leapt forward over the past decade. But the progress toward widescale commercialization of some clean energy technologies should not obscure the significant research and development needs remaining. Some 96 percent of the technologies needed to decarbonize aviation, for example, are still in the prototype or demonstration phase,[135] as are nearly a third of the technologies needed to decarbonize iron and steel.[136] Sustained public investment in clean energy research and development, beyond the ten-year horizon envisioned in the IRA, will be crucial to bringing these and other innovations from the drawing board to the board room.

While the recent influx of federal funds is an important milestone, the U.S. is still lagging far behind in investments compared to its competitors. Today, China accounts for nearly half of the world's low-carbon spending, and manufacturing of low-carbon energy technologies like solar panels and batteries. In 2022, China spent $546 billion on clean energy investments—nearly four times the amount of U.S. investments. Meanwhile, the European Union spent $180 billion compared to the U.S. $141 billion.[137] While the unprecedented funding and incentives from the IRA, IIJA, and CHIPS and Science Act provide a critical foundation for innovation and deployment, sustained further funding will be essential to bringing the clean energy economy to fruition.

Facilitate Private Sector Investment

It is difficult to overstate the scale of the economic transition that the U.S. and other countries must catalyze in the coming decade. Though the sums that the IRA, IIJA, and other federal actions have directed to clean energy innovation run into the hundreds of billions of dollars, even with sustained federal funding, the need will vastly outrun public resources. To meet the 1.5°C Paris goal, the IPCC estimates that the world will need to invest an average of *$2.38 trillion* annually in the energy sector to 2035, and up to three times as much to transition transportation and other sectors as well.[138] The public sector should therefore work to harness the much larger resources of the private sector toward this critical goal.

The IRA and the IIJA already include substantial subsidies to would-be producers of renewable energy, hydrogen, and carbon capture technologies—potentially foundational industries to a net-zero future. Though these subsidies are nominally time-limited, public support has a way of becoming institutionalized, even after questions can reasonably be raised about their value. As technology advances in the coming decades, new decarbonization options may arise that would offer even greater public benefit than the technologies currently being supported if they could make their way from the lab to the market. Congress, together with experts from the Department of Energy, academia, and industry, should therefore collaborate on regular reviews of public subsidies to ensure they are targeted to the most promising innovations and adequate to catalyze meaningful progress.

To be sustainable, a market needs both supply and demand. Policymakers should therefore work to expand forward purchase arrangements like the First Movers Coalition, in which participating companies commit to buying nascent clean energy technologies to support their journey to market. Participation in the Coalition, organized in part by the U.S. State Department, is voluntary and (at $12 billion worth of purchase commitments) a laudable but still experimental part of the portfolios of the participants' $8 trillion market value.[139] The United States should work with its diplomatic and corporate partners to build participation in the FMC and organizations like it, and Congress should consider ways to incentivize similar forward purchase arrangements through the tax code. Policymakers should also look for additional ways to bolster demand for clean energy and fuels through civilian and military procurement, serving as a reliable customer for low-carbon materials and technologies.

Globalize Innovation

During the Second World War, the U.S. famously served as the "Arsenal of Democracy"—a critical source of technological and material support for friendly countries facing an existential foe. Today, as the U.S. races to develop and deploy clean energy technologies, it should take similar steps to ensure that the innovations of U.S. companies are shared with the world. At the most basic level, the U.S. and its international partners should meet their commitment to mobilize $100 billion in annual climate funding for poorer countries. As part of that effort, Washington should work through the U.S. Agency for International Development and the U.S. Development Finance Corporation to ensure that low- and middle-income countries can access clean energy innovations and leverage additional financing from international financial institutions toward the same goal. Washington should also explore changes to federal patenting rules that grant full intellectual property rights to institutions that make federally funded discoveries. While it is critical that green industries are profitable and ultimately self-sustaining, reforms to patent laws could help ease the dissemination of clean energy technologies without threatening the profit motive.[140]

Endnotes

[1] Philip Bump, "The Long History of Linking Climate Change to American Security," *Washington Post*, May 20, 2015, https://www.washingtonpost.com/news/the-fix/wp/2015/05/20/the-long-history-of-linking-climate-change-to-american-security.

[2] Secretary of Defense, "Quadrennial Defense Review Report", February 2010, https://dod.defense.gov/Portals/1/features/defenseReviews/QDR/QDR_as_of_29JAN10_1600.pdf

[3] Department of Defense, "Quadrennial Defense Review 2014", March 2014, https://history.defense.gov/Portals/70/Documents/quadrennial/QDR2014.pdf?ver=tXH94SVvSQLVw-ENZ-a2pQ%3d%3d

[4] The Executive Office of the President, "Tackling the Climate Crisis at Home and Abroad", The Daily Journal of the United States Government, National Archives, January 27, 2021, https://www.federalregister.gov/documents/2021/02/01/2021-02177/tackling-the-climate-crisis-at-home-and-abroad.

[5] Jessica Olcott Yllemo and Thomas Benson, "2021-2022 Defense Climate Highlights and Case Studies," American Security Project, November 14, 2022, https://www.americansecurityproject.org/2021-2022-u-s-defense-climate-highlights/.

[6] Jessica Olcott Yllemo and Sarah Nishioka, "National Security and Electric Vehicles," American Security Project, April 19, 2022, https://www.americansecurityproject.org/fact-sheet-national-security-and-electric-vehicles-ev/.

[7] J.E. Jack Surash and Robert Hughes, "Developing Microgrids to Deliver Energy Resilience," U.S. Army, April 12, 2022. https://www.army.mil/article/255597/developing_microgrids_to_deliver_energy_resilience.

[8] Department of the Army, "Climate Strategy", Office of the Assistant Secretary of the Army for Installations, Energy and Environment. February 2022, p.7, https://www.army.mil/e2/downloads/rv7/about/2022_army_climate_strategy.pdf

[9] Department of the Air Force, "Climate Action Plan", Office of the Assistant Secretary for Energy, Installations, and Environment, October 2022, p.6, https://www.safie.hq.af.mil/Portals/78/documents/Climate/DAF%20Climate%20Action%20Plan.pdf?ver=YcQAZsGM_Xom3DkNP_fL3g%3d%3d.

[10] Department of the Navy, "Climate Action 2030," May 24, 2022, p 10, https://media.defense.gov/2022/May/24/2003004208/-1/-1/0/220524-N-NO191-0001.JPG.

[11] Department of Defense, "Climate Adaptation Plan", September 1, 2021, p. 23, https://www.sustainability.gov/pdfs/dod-2021-cap.pdf

[12] "DIU Leverages Commercial Technology to Drive Climate and Energy Resilience," Defense Innovation Unit, April 21, 2023, https://www.diu.mil/latest/diu-leverages-commercial-technology-to-drive-climate-and-energy-resilience

[13] U.S. Department of Defense (DOD), "2022 National Defense Strategy of the United States of America," October 27, 2022, 4, https://media.defense.gov/2022/Oct/27/2003103845/-1/-1/1/2022-NATIONAL-DEFENSE-STRATEGY-NPR-MDR.PDF.

[14] "Greenhouse Gas Emissions by Top Emitters, 2018," Global Emissions, Center for Climate and Energy Solutions, accessed April 6, 2023, https://www.c2es.org/content/international-emissions.

[15] Karl Mathiesen *et al*, "U.S. and China Step to Forefront as Climate Talks Near End Game," *Politico*, November 10, 2021, https://www.politico.com/news/2021/11/10/us-china-climate-talks-cooperation-520686.

[16] Keith Zhai, "China Set to Create New State-Owned Rare-Earths Giant," *The Wall Street Journal*, December 3, 2021, https://www.wsj.com/articles/china-set-to-create-new-state-owned-rare-earths-giant-11638545586.
[17] Office of the Director of National Intelligence (ODNI), "Annual Threat Assessment of the U.S. Intelligence Community," February 6, 2023, 9-10, https://www.dni.gov/files/ODNI/documents/assessments/ATA-2023-Unclassified-Report.pdf.
[18] Conall Heussaff *et al*, "Russian Crude Oil Tracker," Breugel, last updated March 13, 2023, https://www.bruegel.org/dataset/russian-crude-oil-tracker.
[19] "Energy Fact Sheet: Why Does Russian Oil and Gas Matter?," International Energy Agency, March 21, 2022, https://www.iea.org/articles/energy-fact-sheet-why-does-russian-oil-and-gas-matter.
[20] Georg Zachmann *et al*, "European Natural Gas Imports," Breugel, last updated April 19, 2023, https://www.bruegel.org/dataset/european-natural-gas-imports.
[21] Raf Casert *et al*, "Europe Faces Pressure to Join U.S., British Ban on Russian Oil," *Associated Press*, March 9, 2022, https://apnews.com/article/russia-ukraine-putin-business-european-union-germany-60cd9af0e990d0e95547d2c7052f898f.
[22] America's Strategy to Secure the Supply Chain for a Robust Clean Energy Transition, February 24, 2022, https://www.energy.gov/policy/articles/americas-strategy-secure-supply-chain-robust-clean-energy-transition.
[23] BloombergNEF, "New Study; Clean Energy Transition Now Hard-Wired into the U.S. Economy", BloombergNEF, March 1, 2023. https://about.bnef.com/blog/new-study-clean-energy-transition-now-hard-wired-into-the-u-s-economy/.
[24] Devashree Saha, Rajat Shrestha and Phil Jordan, "How a Clean Energy Economy Can Create Millions of Jobs in the US," World Resources Institute, September 14, 2022. https://www.wri.org/insights/us-jobs-clean-energy-growth.
[25] The Executive Office of the President, "Tackling the Climate Crisis at Home and Abroad", The Daily Journal of the United States Government, National Archives, January 27, 2021, https://www.federalregister.gov/documents/2021/02/01/2021-02177/tackling-the-climate-crisis-at-home-and-abroad.
[26] https://www.whitehouse.gov/briefing-room/presidential-actions/2021/02/24/executive-order-on-americas-supply-chains/.
[27] The White House, "Executive Order on Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability", December 8, 2021, https://www.whitehouse.gov/briefing-room/presidential-actions/2021/12/08/executive-order-on-catalyzing-clean-energy-industries-and-jobs-through-federal-sustainability/.
[28] U.S. Department of Energy, "President Biden Invokes Defense Production Act to Accelerate Domestic Manufacturing of Clean Energy." June 06, 2022. https://www.energy.gov/articles/president-biden-invokes-defense-production-act-accelerate-domestic-manufacturing-clean.
[29] "Innovating Out of the Climate Crisis: Hard to Abate Sectors," American Security Project, April 5, 2023, https://www.americansecurityproject.org/event-recap-innovating-out-of-the-climate-crisis-hard-to-abate-sectors/.
[30] Morgan Higman, Lachlan Carey, and Stephen J. Naimoli, "The Infrastructure Investment and Jobs Act Will Do More to Reach 2050 Climate Targets than Those of 2030," Center for Strategic and International Studies, August 18, 2021, https://www.csis.org/analysis/infrastructure-investment-and-jobs-act-will-do-more-reach-2050-climate-targets-those-2030
[31] Margaret Oloriz, Calvin Tong, Alyssa Ramierex, and Niki Shah, "The utility of now: How the IIJA and IRA are expediting the 'utility of the future' into the present," West Monroe, November 2022, https://www.westmonroe.com/perspectives/point-of-view/utility-of-now-how-iija-ira-expediting-utility-of-the-future
[32] "Fact Sheet: The Bipartisan Infrastructure Bill," The White House, November 6, 2021, accessed April 23, 2023, https://www.whitehouse.gov/briefing-room/statements-releases/2021/11/06/fact-sheet-the-bipartisan-infrastructure-deal.
[33] "Investments in Electric and Low-Emission School Buses," Environmental Protection Agency, accessed April 23, 2023, https://www.epa.gov/infrastructure/investments-electric-and-low-emission-school-buses.
[34] https://www.whitehouse.gov/briefing-room/statements-releases/2021/11/08/fact-sheet-the-bipartisan-infrastructure-deal-boosts-clean-energy-jobs-strengthens-resilience-and-advances-environmental-justice/.
[35] U.S. Department of Energy, "Building a Better Grid Initiative," January 12, 2022, https://www.energy.gov/oe/articles/building-better-grid-initiative
[36] "Fact Sheet: The Bipartisan Infrastructure Bill," The White House, November 6, 2021, accessed April 23, 2023, https://www.whitehouse.gov/briefing-room/statements-releases/2021/11/06/fact-sheet-the-bipartisan-infrastructure-deal.
[37] Mariana Amrbose, John Jacobs, and Natalie Tham, "CHIPS and Science Act Summary: Energy, Climate, and Science Provisions," Bipartisan Policy Center, November 14, 2022, https://bipartisanpolicy.org/blog/chips-science-act-summary/.
[38] National Science Foundation, Technology, Innovation, and Partnerships, https://beta.nsf.gov/tip/latest.
[39] Matt Furlow, "How Passage of the Chips and Science Act is Advancing R&D in America," U.S. Chamber of Commerce, January 10, 2023, https://www.uschamber.com/technology/how-passage-of-the-chips-and-science-act-is-advancing-r-d-in-america#:~:text=Unlike%20the%20investments%20made%20in,action%20in%20the%20years%20ahead.
[40] EELP Staff, "The Inflation Reduction Act's Implications for Biden's Climate and Environmental Justice Priorities," Environmental & Energy Law Program, August 12, 2022, https://eelp.law.harvard.edu/2022/08/ira-implications-for-climate-ej-priorities/.
[41] Ibid.

[42] "Inflation Reduction Act (IRA) Summary: Energy and Climate Provisions," Bipartisan Policy Center, August 4, 2022, https://bipartisanpolicy.org/blog/inflation-reduction-act-summary-energy-climate-provisions/.
[43] Ibid.
[44] Ibid.
[45] John Larsen et al, "A Turning Point for US Climate Progress: Assessing the Climate and Clean Energy Provisions in the Inflation Reduction Act," Rhodium Group, August 12, 2022, https://rhg.com/research/climate-clean-energy-inflation-reduction-act/.
[46] Stefan Ellerbeck, "Here's how the Inflation Reduction Act is impacting green job creation," World Economic Forum, March 14, 2023. https://www.weforum.org/agenda/2023/03/us-climate-bill-green-jobs/.
[47] "Priority Energy Communities," Interagency Working Group on Coal & Power Plant Communities & Economic Revitalization, https://energycommunities.gov/priority-energy-communities/.
[48] Philip Gordon, "The aging workforce's brain drain," Smart Energy International, September 2, 2019. https://www.smart-energy.com/industry-sectors/energy-grid-management/the-ageing-workforces-brain-drain/ .
[49] Intergovernmental Panel on Climate Change (IPCC), "AR 5 Summary for Policymakers," p. 4.
[50] Robinson Meyer, "Congress Just Passed a Big Climate Bill. No, Not That One." The Atlantic, August 10, 2022, https://www.theatlantic.com/science/archive/2022/08/chips-act-climate-bill-biden/671095/.
[51] Fourth National Climate Assessment, Chapter 10: Agriculture and Rural Communities, https://nca2018.globalchange.gov/chapter/10/.
[52] Lindsay Iversen, "Innovating Out of the Climate Crisis: Agricultural Technology," American Security Project, February 28, 2023, https://www.americansecurityproject.org/innovating-out-of-the-climate-crisis-agricultural-technology/.
[53] Ibid.
[54] J Rising, and Devineni, N, "Crop switching reduces agricultural losses from climate change in the United States by half under RCP 8.5," Climate Impact Lab, October 5, 2020, https://impactlab.org/research/crop-switching-reduces-agricultural-losses-from-climate-change-in-the-united-states-by-half-under-rcp-8-5/
[55] Lindsay Iversen, "Innovating Out of the Climate Crisis: Agricultural Technology," American Security Project, February 28, 2023, https://www.americansecurityproject.org/innovating-out-of-the-climate-crisis-agricultural-technology/
[56] U.S. Department of Agriculture, "Precision Agriculture in Crop Production," National Institute of Food and Agriculture, https://www.nifa.usda.gov/grants/programs/precision-geospatial-sensor-technologies-programs/precision-agriculture-crop-production
[57] Dan Blaustein-Rejto *et al*, "From Lab to Farm: Assessing Federal R&D Funding for Agricultural Climate Mitigation," The Breakthrough Institute, December 12, 2022, https://thebreakthrough.org/issues/food-agriculture-environment/from-lab-to-farm.
[58] Michael Doane *et al*, "reThink Soil: A Roadmap for U.S. Soil Health," The Nature Conservancy, January 2, 2020, https://www.nature.org/content/dam/tnc/nature/en/documents/rethink-soil-executive-summary.pdf.
[59] Lindsey Iversen, "Innovating Out of the Climate Crisis: Agricultural Technology," American Security Project, February 28, 2023, https://www.americansecurityproject.org/innovating-out-of-the-climate-crisis-agricultural-technology/.
[60] "Public and Private Agricultural and Food Research and Development (R&D) Expenditures, Real (Inflation Adjusted) Dollars, 1970-2019," U.S. Department of Agriculture, Economic Research Service, last updated May 17, 2022, https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=56079.
[61] Michael Happ, "Closed Out: How U.S. Farmers are Denied Access to Conservation Programs," Institute for Agriculture and Trade Policy, September 9, 2021, https://www.iatp.org/documents/closed-out-how-us-farmers-are-denied-access-conservation-programs.
[62] U.S. Department of Agriculture, "Biden-Harris Administration Announces Availability of Inflation Reduction Act Funding for Climate-Smart Agriculture Nationwide," USDA, February 13, 2023, https://www.usda.gov/media/press-releases/2023/02/13/biden-harris-administration-announces-availability-inflation.
[63] "Partnerships for Climate-Smart Commodities," U.S. Department of Agriculture, accessed April 22, 2023, https://www.usda.gov/climate-solutions/climate-smart-commodities.
[64] "What is the Farm Bill," National Sustainable Agriculture Coalition, https://sustainableagriculture.net/our-work/campaigns/fbcampaign/what-is-the-farm-bill/.
[65] Valerie Masson-Delmotte *et al*, "Summary for Policymakers" in *Global Warming of 1.5C: An IPCC Special Report on the imipacts of Global Warming of 1.5C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emissions Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*, (Cambridge: Cambridge University Press, 2018), accessed April 23, 2023, https://www.ipcc.ch/sr15/chapter/spm.
[66] David Roberts, "Could Squeezing More Oil Out of the Ground Help Fight Climate Change?," *Vox*, December 6, 2019, https://www.vox.com/energy-and-environment/2019/10/2/20838646/climate-change-carbon-capture-enhanced-oil-recovery-eor.
[67] Dr. Eva Amsen, "CCS and CCU. Mind explaining what these are again?" NESTE, April 21, 2021 https://journeytozerostories.neste.com/circular-economy/ccs-and-ccu-mind-explaining-what-these-are-again.

[68] "Innovating Out of the Climate Crisis: Carbon Emissions," American Security Project, January 26, 2023, https://www.americansecurityproject.org/innovating-out-of-the-climate-crisis-carbon-emissions/.
[69] Mark Dwortzan, "Stranded Assets Could Exact Steep Costs on Fossil Energy Producers and Investors," MIT News, August 19, 2022, https://news.mit.edu/2022/stranded-assets-could-exact-steep-costs-fossil-energy-producers-investors-0819.
[70] Ibid.
[71] "The Inflation Reduction Act Includes Significant Benefits for the Carbon Capture Industry," Gibson Dunn, August 16, 2022, https://www.gibsondunn.com/the-inflation-reduction-act-includes-significant-benefits-for-the-carbon-capture-industry.
[72] Innovating Out of the Climate Crisis: Carbon Emissions," American Security Project, January 26, 2023, https://www.americansecurityproject.org/innovating-out-of-the-climate-crisis-carbon-emissions/
[73] Ibid.
[74]U.S. Department of Energy, "Fossil Energy and Carbon Management: Carbon Dioxide Removal Frequently Asked Questions," https://www.energy.gov/sites/default/files/2022-07/Carbon-Dioxide-Removal-FAQs_7.8.22.pdf
[75] U.S. Department of State, "First Movers Coalition Announces Expansion", November 9, 2022. https://www.state.gov/first-movers-coalition-announces-expansion/
[76] https://www.americansecurityproject.org/innovating-out-of-the-climate-crisis-carbon-emissions/
[77] Margaret Cook *et al*, "Electrification on the Road to Net Zero: A Comparison of Studies Examining Opportunities and Barriers in the United States," Columbia Center on Global Energy Policy, October 2022, 10, https://www.energypolicy.columbia.edu/sites/default/files/pictures/Electrification-CGEP_Report_101022.pdf.
[78] Steven Cicala, "Decarbonizing the U.S. Economy with a National Grid," in *U.S. Energy & Climate Roadmap: Evidence-based Policies for Effective Action*," ed. Lindsay Iversen (Chicago: Energy Policy Institute at the University of Chicago, 2021), 79.
[79] IRENA, "Renewable Power Generation Costs in 2021," International Renewable Energy Agency, 2022, 4, https://www.irena.org/publications/2022/Jul/Renewable-Power-Generation-Costs-in-2021.
[80] Richard Campbell, "The Smart Grid: Status and Update," Congressional Research Service, April 10, 2018, 2, https://crsreports.congress.gov/product/pdf/R/R45156.
[81] "AMI: Fundamentals of Advanced Metering Infrastructure," Eaton.com, accessed April 8, 2023, https://www.eaton.com/us/en-us/products/utility-grid-solutions/advanced-metering-infrastructure/fundamentals-of-ami.
[82] Cicala, "Decarbonizing," 79.
[83] "A 2030 United States Macro Grid," Breakthrough Energy Sciences, January 2021, 6, https://bescdn.breakthroughenergy.org/publications/MacroGridReport.pdf.
[84] Paul Denholm *et al*, "Examining Supply-Side Options to Achieve 100% Clean Electricity by 2035," National Renewable Energy Laboratory, 2022, xi, https://www.nrel.gov/docs/fy22osti/81644.pdf.
[85] Jonathan Moch and Henry Lee, "The Challenges of Decarbonizing the U.S. Electric Grid by 2035," Belfer Center for Science and International Affairs, February 2022, https://www.belfercenter.org/publication/challenges-decarbonizing-us-electric-grid-2035.
[86] BloombergNEF, "Battery Pack Prices Cited Below $100/kWh for the First Time in 2020, While Market Average Sits at $137/kWh," BloombergNEF Blog, December 16, 2020, https://about.bnef.com/blog/battery-pack-prices-cited-below-100-kwh-for-the-first-time-in-2020-while-market-average-sits-at-137-kwh.
[87] Venkat Srinivasan, "Innovating Out of the Climate Crisis: Electrification," interview with Jessica Olcott Yllemo, American Security Project, November 21, 2022, https://www.americansecurityproject.org/event-recap-innovating-out-of-the-climate-crisis-electrification.
[88] Tisha Scroggin-Wicker and Kieran McInerney, "Flow Batteries: Energy Storage Option for a Variety of Uses," *Power*, March 2, 2020, https://www.powermag.com/flow-batteries-energy-storage-option-for-a-variety-of-uses.
[89] Alasdair Lane, "Can Gravity Batteries Solve our Energy Storage Problems?," *BBC Future Planet*, May 16, 2022, https://www.bbc.com/future/article/20220511-can-gravity-batteries-solve-our-energy-storage-problems.
[90] "Compressed Air Energy Storage: Future Ideas," TheGreenAge.com, April 30, 2013, https://www.thegreenage.co.uk/tech/compressed-air-energy-storage.
[91] Katie Brigham, "Why Hydropower is the Forgotten Giant of Clean Energy," *CNBC*, June 2, 2022, https://www.cnbc.com/2022/06/02/why-hydropower-is-the-worlds-most-overlooked-renewable.html.
[92] "Innovating Out of the Climate Crisis: Electrification," American Security Project, November 21, 2022, https://www.americansecurityproject.org/event-recap-innovating-out-of-the-climate-crisis-electrification.
[93] "The Inflation Reduction Act," U.S. Environmental Protection Agency, accessed April 22, 2023, https://www.epa.gov/green-power-markets/inflation-reduction-act.
[94] Owen Minott and Helen Ngyuen, "IRA EV Tax Credits: Requirements ofr Domestic Manufacturing," Bipartisan Policy Center, February 24, 2023, https://bipartisanpolicy.org/blog/ira-ev-tax-credits.
[95] "Federal Income Tax Credits and Incentives for Energy Efficiency," EnergyStar.gov, accessed April 22, 2023, https://www.energystar.gov/about/federal_tax_credits.

[96] Lindsay Iversen and Jessica Olcott Yllemo, "Innovating Out of the Climate Crisis: Electrification," American Security Project, November 23, 2022, https://www.americansecurityproject.org/innovating-out-of-the-climate-crisis-electrification/.
[97] "Building a Better Grid Initiative," U.S. Department of Energy Office of Electricity, January 12, 2022, accessed April 8, 2023, https://www.energy.gov/oe/articles/building-better-grid-initiative.
[98] Jonathan Brightbill, "Will the Infrastructure Investment and Jobs Act Accelerate Transmission Development?," Winston & Strawn LLP, January 4, 2022, https://www.winston.com/en/winston-and-the-legal-environment/will-the-infrastructure-investment-and-jobs-act-accelerate-transmission-development.html.
[99] "Infrastructure Investment and Jobs Act Boosts U.S. Supply Side Investments in Energy Storage," Energy Storage Association, December 2021, https://energystorage.org/wp/wp-content/uploads/2021/12/Summary-of-Infrastucture-Investment-and-Jobs-Act-12_9_2021.pdf.
[100] "Long Duration Storage Shot," U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE), accessed April 22, 2023, https://www.energy.gov/eere/long-duration-storage-shot.
[101] "Inflation Reduction Act Creates New Tax Credit Opportunities for Energy Storage Projects," McGuireWoods, December 27, 2022, https://www.mcguirewoods.com/client-resources/Alerts/2022/12/inflation-reduction-act-creates-new-tax-credit-opportunities-for-energy-storage-projects.
[102] Andrew Tarantola, "We Won't Have Electric Airplanes Until Battery Tech Improves," *Engadget*, October 29, 2021, https://www.engadget.com/we-wont-have-electric-airplanes-until-battery-tech-improves-160058357.html.
[103] Lindsay Iversen, "Innovating Out of the Climate Crisis: Hard to Abate Sectors," American Security Project, April 7, 2023, https://www.americansecurityproject.org/briefing-note-innovating-out-of-the-climate-crisis-hard-to-abate-sectors/.
[104] "Innovating Out of the Climate Crisis: Hard to Abate Sectors," American Security Project, April 5, 2023, https://www.americansecurityproject.org/event-recap-innovating-out-of-the-climate-crisis-hard-to-abate-sectors/.
[105] U.S. Department of Energy, "DOE Industrial Decarbonization Roadmap," https://www.energy.gov/eere/doe-industrial-decarbonization-roadmap.
[106] Lindsay Iversen, "Innovating Out of the Climate Crisis: Hard to Abate Sectors," American Security Project, April 7, 2023, https://www.americansecurityproject.org/briefing-note-innovating-out-of-the-climate-crisis-hard-to-abate-sectors/.
[107] "The Future of Hydrogen," International Energy Agency, June 2019, https://www.iea.org/reports/the-future-of-hydrogen.
[108] "Global Cumulative CO2 Emissions Reductions in Aviation by Technology Readiness Level in the Sustainable Development Scenario Relative to the Stated Policies Scenario, 2019-2070," International Energy Agency, last updated October 26, 2022, https://www.iea.org/data-and-statistics/charts/global-cumulative-co2-emissions-reductions-in-aviation-by-technology-readiness-level-in-the-sustainable-development-scenario-relative-to-the-stated-policies-scenario-2019-2070.
[109] "Cumulative Direct Emissions Reductions by Current Technology Maturity Category in the Sustainable Development Scenario between 2020 and 2050," International Energy Agency, last updated October 26, 2022, https://www.iea.org/data-and-statistics/charts/cumulative-direct-emission-reductions-by-current-technology-maturity-category-in-the-sustainable-development-scenario-between-2020-and-2050.
[110] Lindsay Iversen, "Innovating Out of the Climate Crisis: Hard to Abate Sectors," American Security Project, April 7, 2023, https://www.americansecurityproject.org/briefing-note-innovating-out-of-the-climate-crisis-hard-to-abate-sectors/.
[111] "The Inflation Reduction Act Includes Significant Benefits for the Carbon Capture Industry," Gibson Dunn, August 16, 2022, https://www.gibsondunn.com/the-inflation-reduction-act-includes-significant-benefits-for-the-carbon-capture-industry.
[112] Megan Boutwell, "Inflation Reduction Act Sustainable Aviation Fuel Credit," Stillwater Associates, September 7, 2022, https://stillwaterassociates.com/inflation-reduction-act-sustainable-aviation-fuel-credit-carbon-intensity-matters .
[113] "First Movers Coalition," World Economic Forum, accessed April 23, 2023, https://www.weforum.org/first-movers-coalition.
[114] Lindsay Iversen, "Innovating Out of the Climate Crisis: Hard to Abate Sectors," American Security Project, April 7, 2023, https://www.americansecurityproject.org/briefing-note-innovating-out-of-the-climate-crisis-hard-to-abate-sectors/.
[115] Jessica Olcott Yllemo, "'Climate Security in Focus: Clean' and 'Green' Hydrogen, American Security Project, October 6, 2022, https://www.americansecurityproject.org/clean-and-green-hydrogen/.
[116] "Hydrogen Production," U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE), accessed April 7, 2023, https://www.energy.gov/eere/fuelcells/hydrogen-production.
[117] Fuel Cell Technologies Office, "Hydrogen Production," EERE, June 2016, 1, https://www.energy.gov/eere/fuelcells/articles/hydrogen-production-fact-sheet.
[118] Fang Yan *et al*, "Why Should We Care About Hydrogen Carbon Intensity?," ICF, September 23, 2022, https://www.icf.com/insights/energy/care-about-hydrogen-carbon-intensity.
[119] https://www.energymatters.com.au/renewable-news/clean-vs-green-hydrogen-whats-the-difference/#:~:text=The%20process%20of%20creating%20green,and%20storage%20(CCS)%20technology.

[120] "Levelised Cost of CO_2 Capture by Sector and Initial CO_2 Concentration, 2019," International Energy Agency, last updated October 26, 2022, https://www.iea.org/data-and-statistics/charts/levelised-cost-of-co2-capture-by-sector-and-initial-co2-concentration-2019."
[121] Niall Mac Dowell *et al*, "The Hydrogen Economy: A Pragmatic Path Forward," *Joule* 5, no. 10 (October 20, 2021): 2527, https://doi.org/10.1016/j.joule.2021.09.014.
[122] U.S. Department of Energy, "DOE Establishes Bipartisan Infrastructure Law's $9.5 Billion Clean Hydrogen Initiatives," February 15, 2022, https://www.energy.gov/articles/doe-establishes-bipartisan-infrastructure-laws-95-billion-clean-hydrogen-initiatives.
[123] Ibid.
[124] Mac Dowell, "The Hydrogen Economy."
[125] "Hydrogen Shot," EERE, accessed April 7, 2023, https://www.energy.gov/eere/fuelcells/hydrogen-shot.
[126] Fang *et al*, "Why Should We Care."
[127] Emily Kent, "Innovating Out of the Climate Crisis: Hydrogen," interview with Jessica Olcott Yllemo, American Security Project, December 13, 2022, https://www.americansecurityproject.org/event-recap-innovating-out-of-the-climate-crisis-hydrogen.
[128] Dana Nuccitelli, "Permitting: America's next big climate conundrum," Yale Climate Connections, October 11, 2022, https://yaleclimateconnections.org/2022/10/permitting-americas-next-big-climate-conundrum/.
[129] Jessica Olcott Yllemo, "Climate Security in Focus: Expediting Electricity Transmission," American Security Project, December 01, 2022, https://www.americansecurityproject.org/expediting-electricity-transmission/.
[130] Princeton University Zero Lab, "Electricity Transmission is Key to Unlock the Full Potential of the Inflation Reduction Act," September 2022, https://repeatproject.org/docs/REPEAT_IRA_Transmission_2022-09-22.pdf.
[131] Jeremy Harrell, "Innovating Out of the Climate Crisis: Hard to Abate Sectors," interview with Jessica Olcott Yllemo, American Security Project, April 4, 2023, https://www.americansecurityproject.org/event-recap-innovating-out-of-the-climate-crisis-hard-to-abate-sectors.
[132] Jeremy Dillon, "Senate Hope for Permit Deal Alive After DOA House Energy Bill," *E&E Daily*, March 16, 2023, https://www.eenews.net/articles/senate-hope-for-permit-deal-alive-after-doa-house-energy-bill.
[133] U.S. Department of Energy, National Transmission Needs Study, https://www.energy.gov/gdo/national-transmission-needs-study.
[134] The Biden-Harris Permitting Action Plan to Rebuild America's Infrastructure, Accelerate the Clean Energy Transition, Revitalize Communities, and Create Jobs, https://www.whitehouse.gov/wp-content/uploads/2022/05/Biden-Harris-Permitting-Action-Plan.pdf
[135] "Global Cumulative CO_2 Emissions Reductions in Aviation by Technology Readiness Level in the Sustainable Development Scenario Relative to the Stated Policies Scenario, 2019-2070," International Energy Agency, accessed April 9, 2023, https://www.iea.org/data-and-statistics/charts/global-cumulative-co2-emissions-reductions-in-aviation-by-technology-readiness-level-in-the-sustainable-development-scenario-relative-to-the-stated-policies-scenario-2019-2070.
[136] "Iron and Steel Technology Roadmap," International Energy Agency, accessed April 9, 2023, https://www.iea.org/reports/iron-and-steel-technology-roadmap.
[137] Sarah Schonhardt, "China Invests $546 Billion in Clean Energy, Far Surpassing the U.S.", Scientific American, January 30, 2023. https://www.scientificamerican.com/article/china-invests-546-billion-in-clean-energy-far-surpassing-the-u-s.
[138] Heleen de Coninck *et al*, "Strengthening and Implementing the Global Response," in *Global Warming of 1.5°C. An IPCC Special Report on the Impacts Of Global Warming of 1.5°C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, In the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts To Eradicate Poverty*, (Cambridge, UK and New York, NY: Cambridge University Press, 2018), https://www.ipcc.ch/sr15/chapter/chapter-4.
[139] "Tackling the Climate Crisis with Innovative Green Technologies," World Economic Forum, accessed April 9, 2023, https://www.weforum.org/impact/first-movers-coalition-is-tackling-the-climate-crisis.
[140] Lisa Larrimore Ouellette, "Addressing the Green Patent Global Deadlock Through Bayh-Dole Reform," *The Yale Law Journal* 119, No. 7 (May 2010), 1728, https://www.jstor.org/stable/25681952.

The American Security Project (ASP) is a nonpartisan organization created to educate the American public and the world about the changing nature of national security in the 21st Century.

Our Mission:

To communicate our vision for security in the 21st century by developing and sharing new ideas and critical analyses on the most important national security issues of our time;

To forge a bipartisan consensus on a new national security strategy that will restore America's leadership and ensure our security;

To raise the American public's understanding of critical national security issues through direct engagement and dialogue.

ASP
American Security Project