Yale Energy Studies
SOCIETY - TECHNOLOGY - ENVIRONMENT

Class of 2024 Yale Energy Scholars
Class of 2024 Yale Energy Scholars

37 Graduating with Energy Studies Certificates in May 2024
(Several from the original Class of 2024 delaying to next Fall or Spring)

39 B.S. or B.A. Degrees, 1 Master of Music (Violin)

18 Yale University Departments Represented
This case study considers possible operations for Rocky River Hydropower Plant in 2035. This year, we assume that the grid will be composed of 95% renewable energy. In such a situation, the operational strategy for hydropower, and in our case pumped storage hydropower, will change. To project the operations for this year, we consider the environmental, hydrologic, financial, and social parameters for Rocky River.

Rocky River Hydropower Plant was first created in 1929 in Milford, Connecticut and lies alongside the Housatonic River. Rocky River is the first pumped storage hydropower facility constructed in the United States. It pumps water from the Housatonic River into Candlewood Lake, an artificial lake located approximately 200 ft in elevation above the river. Candlewood Lake is bordered by many housing properties that use the lake for recreational purposes. Owned by FirstLight Power, Rocky River is operated in conjunction with three other dams owned by FirstLight on the Housatonic River.

As renewable energy becomes a stronger influence in the energy grid, it is imperative that facilities such as Rocky River consider how they can best operate to support this greener future.

Prizes awarded to the Yale team at HCC 2023: Second Place: Overall HCC Competition; First Place: Creating Connections Challenge. Team consisted of Katrina Starbird (Team Lead), Shayaan Subzwari, Neal Ma, Maddie Bartels, Selin Goren, and Ruth Lee.
The winners of the 2023 HCC are:

- First place: Endicott College
- Second place: Yale University
- Third place: Northern Arizona University

Individual category winners are:

- Best Poster: Texas Tech University
- Case Study Contest: Endicott College
- Connection Creation Contest: Yale University
The Yale team won 2nd place in the first annual Hydropower Collegiate Competition (HCC) organized by the Department of Energy! 🌊⚡️🙌

The team consisted of Energy Studies students Katrina Starbird (EPS'23), Neal Ma (Physics'23), Shayaan Subzwari (Physics'23), Maddie Bartels (EPS'23.5), Selin Gören (EVST'24), Ruth Lee (Undeclared'25) and was advised by Michael Oristaglio. The team
Wind for Retail: An Internship at BP

Revant Kantamneni ‘24
Pauli Murray | Computer Science & Economics

Today, I’m excited to share insights from my project, “Wind for Retail,” undertaken during my 14-week internship at BP’s Innovation & Engineering Division. I was in Houston my sophomore summer and sat on the broader Wind Energy Team. BP is one of the European energy leaders and back in 2020, set its goal to reach net 0 carbon emissions by 2050. One of the byproducts of that decision was to launch 5 transition growth engines, with one of them being onshore wind. BP’s current onshore wind portfolio includes 9 assets across six states generating 1.7 GW which is the equivalent of fully powering 540,000 homes.

BP has a partnership with ONYX Insight which allowed us to enhance our understanding of turbine component lifespans at our wind farms. By utilizing this technology, we can optimize maintenance schedules, cut costs, and prevent equipment failures. Aside from my intern project, I worked heavily on analyzing various turbine component data and creating dashboards and analytics tools that would help plan maintenance.

BP has a much larger solar portfolio and has already moved ahead with installing solar panels on their retail locations. However, they wanted to apply the same idea to wind power. One of the business objectives of my project was focused on harnessing wind energy for retail locations as part of BP’s commitment to achieving Net Zero by 2050. The dashboard I ultimately designed helped source prospective pilot locations for the installation of small-scale wind turbines on retail locations while wrangling large amounts of time series wind, power usage, and geographical data.

↑ Flowchart analyzing the benefits of installing small-scale wind turbines to provide on-site power for BP retail fuel stations.
A Rhetorical Analysis of Community Responses to Offshore Wind Development in East Hampton, NY

Calista Washburn ‘24

Pauli Murray | Ethics, Politics & Economics

Despite...public support for renewable energy in the abstract, on-the-ground development has faced steady opposition. Since the 1980s, scholars have identified local pushback against renewable energy projects as a crucial “non-technical factor” that prevents the acceptance and progress of renewable energy development in practice. A 2023 report from Columbia University’s Sabin Center for Climate Change Law demonstrates both the prevalence of opposition to specific projects and the ways in which such opposition leads to local and state restrictions on renewable energy development.

This paper uses rhetorical analysis to understand opposition to and support for offshore wind development, a newly emerging field of renewable energy in the U.S. More specifically, this paper analyzes the arguments used by community members writing in opposition to and support of the South Fork Wind Farm, New York State’s first offshore wind farm and the United States’ third. In analyzing these arguments through a rhetorical lens, I seek to understand the underlying values and overarching worldviews that ground local residents’ support for and opposition to the project....I hope to develop a fuller picture of the ways in which core values and understandings of the world inform community responses to offshore wind development.

In sum, many supporters ground their views of South Fork Wind in a value of scientific knowledge, an understanding of the severity of climate change, and a belief in their community’s identity as forward-thinking and environmentally conscious. In contrast, most of the community members who oppose the project do so because they believe it to be a bad deal.
Energy Studies 2024 Field Trip to Yale Record Hill Wind Farm in Maine

50.6 MW of clean renewable energy

Record Hill Wind has built an innovative wind energy farm in Roxbury, Maine. Consisting of twenty-two Siemens 93 2.3 MW turbines along a four mile ridgeline, the project has a nameplate capacity of 50.6 MW. RHW generates power for the community while creating and preserving jobs in rural Maine.
Indonesia’s capital, Jakarta, is sinking at an unprecedented rate. For this reason, the current government proposed to relocate the nation’s capital to Nusantara in Borneo. The project, initiated in 2019, sets out to build an “eco” and “forest” city from the ground up to ensure Indonesia’s sustainable urban future. However, critics argue that the project is causing more environmental and ecological complications than it is alleviating. This paper suggests amendments to the plans for the new capital that would reduce the environmental impacts of relocation. In addition, this paper argues that the value and importance of Jakarta will not diminish regardless of the relocation and that the government must take action to increase the resilience and sustainability of the city.

This paper proposes strategies to retrofit Jakarta and prevent further degradation. Finally, this paper argues that neither city should be considered in isolation or as two contenders for one outcome. On the contrary, the two cities provide opportunities in their own right and for one another; each can guide the other in planning: Nusantara can learn from mistakes made in Jakarta, and Nusantara can serve as a place of innovation and inspiration for Jakarta. In their current form, Jakarta and Nusantara are unsustainable solutions for Indonesia’s urban future. Thus, this paper suggests methods to transform these cities into beacons of hope for the future of urban living in Indonesia, the Southeast Asian region, and the world.
Beginning in the 1950s, hydropower dams have been central to deep-rooted visions of development, especially in developing countries, propagated by politicians, bureaucrats, and international institutions such as the World Bank. Under this vision of prosperity, development has become a top-down, relentless exploitation of natural resources in pursuit of the singular goal of economic growth, with environmental, sociocultural, and humanitarian concerns remaining secondary. Even more than a mere scheme for development, hydropower dams were powerful symbols within regions such as South Asia in the mid-20th century of modernity and independence, or of the conquest of nature....Within India in particular, dams were considered “temples” of modernization and democracy during the Nehruvian period between 1947 and 1964.

In this paper, I will engage in a specific case study of Sikkim, the indigenous Lepcha people, the Dzongu Reserve, and the Teesta River to showcase a complex but demonstrative example of how clashing pro-dam and anti-dam narratives, as well as their evolution alongside each other, have shaped hydropower development in the region. These vigorous debates between a variety of actors have encompassed topics of cultural autonomy, nation-building, and indigenous struggles for prosperity with a sense of dignity.

Using this research, this paper will argue that the Sikkim state government and private developers in India have long propagated a narrative of hydropower being sustainable, due to its purported importance to economic development to uplift “backward” regions and indigenous communities, all under a purely utilitarian, scientifically rational view of the natural world.
Canal leading from Candlewood Lake to Rocky River Hydropower Station (video)
Overcoming Interconnection Bottlenecks for Renewable Energy Deployment in the United States: A Qualitative Analysis

Eli Simon ‘24

Environmental Studies

This thesis addresses the impact of interconnection bottlenecks on the deployment of renewable energy within the United States, identifying the dominant causes and potential solutions. As the U.S. attempts to meet its climate goals through decarbonizing the energy sector, the outdated infrastructure which was designed for predictable electricity generation, struggles to integrate variable solar and wind energy. The technical challenge of preparing legacy infrastructure for renewables has prompted large interconnection waiting times, in turn hampering the feasibility and alacrity of the energy transition.

A qualitative analysis in this thesis details how the existing interconnection process is hindered by physical limitations. Additionally, the thesis investigates the geographic restrictions between renewable generation sites and high-demand areas. The analysis highlights that the current, nominal interconnection queue has collectively exceeded the nation’s current generation capacity, emphasizing the scale of the challenge.

The two strategies discussed in the thesis are the following: enhancing and expanding transmission infrastructure and utilizing distributed energy resources (DERs). It advocates for significant investment in inter-regional transmission development, highlighting many studies that demonstrate its economic benefits. Moreover, the thesis offers two methods of enhancing existing grid infrastructure: advanced reconductoring and dynamic line rates, two options that can materially accelerate the viability of renewable energy resources.

The comprehensive strategies discussed in the paper ultimately highlights efficient methods to meet U.S. decarbonization targets.

↑ Queue of U.S. interconnection capacity by proposed online year. The nation’s interconnection queue has a nominal capacity backlog of over 2,000 gigawatts (GW). For perspective, total existing U.S. generation capacity is approximately 1,300 GW. This interconnection queue consists primarily of renewable generation and battery storage assets. Less than 10% of the interconnection queue has received an interconnection agreement highlighting the speculative nature of many interconnection requests.
Solving the Energy Storage Problem: Iron–Air Batteries

Marco Marsans ’24

My capstone centers on long-duration energy storage (LDES) — specifically, iron-air batteries...The world urgently needs to replace fossil fuels with clean energy sources. At present, solar and wind power are the most promising candidates. However, ...the sun doesn’t always shine, and the wind doesn’t always blow—meaning we cannot reliably power the world off wind and solar without LDES.

Lithium-ion batteries are light and compact [are] great for portable electronics...[but] don’t last very long. In fact, a typical lithium-ion battery lasts for about 8 hours.

Form Energy is the world’s leading iron-air battery company. According to their website, their “first commercial product is an iron-air battery capable of storing electricity for 100 hours at system costs competitive with legacy power plants” (Form) — enough to overcome intermittency for 4 days. This represents an order of magnitude improvement over lithium-ion batteries.

Form’s battery features an air-breathing cathode on one side and an iron anode on the other, both immersed in a water-based, non-flammable electrolyte. As air passes through the cathode, it reacts with the electrolyte, creating negatively charged hydroxide ions [which] create iron hydroxide, commonly known as rust. In that process, they release electrons, which can be guided out of the battery in the form of an electrical current. After 100 hours, the iron is totally rusted through, and the battery runs out. To recharge the battery — aka “unrust” it — an electrical current is sent back through the system, which reverses the reaction, liberating the oxygen from the rust and turning it back into iron. The oxygen leaves the cell in the form of bubbles; meanwhile, the iron is left whole and metallic again.
Talking Trash: Strategies for Reducing Landfill Gas Emissions

Sofia Diggins ‘24

Timothy Dwight | Environmental Studies | Donnelly Prize Essay
CCL Intern and Honorary Energy Studies Scholar

Landfills often fade into the background of our activity space. We dispose of our waste and trust that it will disappear into the depths of wherever the garbage collector takes it. The trash is out of sight and out of mind. However, the reality is far more complex and consequential.

Landfills are not merely repositories for waste; they are significant sources of greenhouse gas emissions, particularly methane, which has a significantly higher global warming potential than carbon dioxide. As organic waste decomposes anaerobically in landfills, it releases methane and volatile organic compounds (VOCs) into the atmosphere, posing profound environmental and health risks, especially for nearby communities. Municipal solid waste (MSW) landfills are a major contributor to methane emissions, ranking as the third-largest source of anthropogenic methane emissions in the United States.

This thesis investigates historical and present regulatory shortcomings in controlling landfill methane emissions. It explores past failures...and proposes new regulatory frameworks to mitigate the worst effects of climate change. By employing an investigative journalism approach, this study includes a literature review, data analysis on landfills, and interviews with key stakeholders, including landfill operators, EPA officials, and waste sector...experts.

[A]lone, regulatory reforms do not sufficiently address the longstanding challenges associated with landfill methane emissions. Economic incentives, however, may expedite the installation of landfill gas collection systems and help control waste sector emissions.
The U.S. energy industry is facing persistent demands for the quick and effective integration of emissions-free energy technologies to meet the federal goal of net-zero emissions by 2050 (White House, 2021, whitehouse.gov).

The emerging nuclear technology of small modular (nuclear) reactors, commonly referred to as “SMRs,” is a way of delivering innovative nuclear technology in modular vessels manufactured centrally and assembled to the appropriate scale on-site. SMRs could provide a flexible power source enabling the US to remodel its energy infrastructure to produce zero-emission energy within an economically competitive system. This technology has the potential to replace the existing US fleet of large nuclear power stations—which provide nearly 20% of US electricity generation but are reaching the end of their useful lifetimes—as well as many coal and natural gas stations within a wide range of applications.

SMRs are still at an early stage of technology development, and numerous economic, social, and policy considerations need to be examined before their commercial development. Economically, SMRs show promising forecasts of returns based on three factors. The first is the technology’s economic competitiveness, projecting lower capital costs than both current fossil fuels and alternative energy sources. The second factor is their modular design, with capabilities to prefabricate 80% of SMR plants, they can be flexibly sited with minimal construction times. The last factor will be their ability to scale and integrate the technology within today’s energy system.

↑ (Top) Classification of small modular (nuclear) reactors or SMRs (Lloyd, 2012) (Bottom) Cost breakdown: Large reactors (LRs) vs SMRs (Carelli, 2021)
“Does a man’s word or a nation’s word ever become obsolete?” – Fighting the Floodwaters on the Fort Berthold Reservation

Hilary Griggs ‘24

History | Branford

The August 24, 1954, edition of the Fort Berthold Agency News Bulletin features a full-page drawing by Denver Horn of the Fort Berthold Reservation. Titled “Destination Unknown,” the sketch depicts a family riding in a wooden wagon pulled by two bony horses. The woman, with an infant strapped to her back, whips the team up the hill, away from the rising floodwaters of the Missouri River behind them. The man, whose long braids and feathered hat identify him as Native American, twists his body around to look at the submerged houses receding in the distance. Treetops peek above the water, marking the disappearing river bottom as lush and verdant, in stark contrast to the rocky, sparse soil on which the family now treads.

The image’s subheading, “Moving Away from The Rising Water Caused by The Garrison Dam,” situates this unknown family in time and space. In 1954, the waters of Lake Sakakawea had been slowly rising for months, eventually submerging over 150,000 acres of land behind the newly-completed Garrison Dam.

This family could have been one of over three hundred Mandan, Hidatsa, and Arikara families whose lives were uprooted by the construction of the Garrison Dam, over eighty percent of the reservation’s population...

As tribal members repeatedly articulated, the United States had violated treaty agreements before, and the Garrison Dam was a continuation of this past betrayal and land theft. However, it was not inertia that made the dam possible, but an active re-affirmation of the past, in which the United States and its agencies recognized that their past land takings were illegal and immoral, and yet decided to do the same again.
Rocky River was a tributary of the Housatonic that was dammed to enlarge Candlewood Lake for recreational activity.
1 of 2 pumps, which also run as generators adding another 5MW of power capacity.
This research looks to explore the relationship in New Haven, CT between “redlining”—a discriminatory housing practice enacted in 1934 by the Home Owners’ Loan Corporation (HOLC)—and current exposure to climate-related health risks, defined as extreme heat, lower prevalence of green space, and increased air pollution.... Exposure to these risks will grow as climate change worsens and will not be evenly distributed across communities. Through a spatial analysis of Landsat satellite imagery, datasets of urban trees and air pollution, and demographic data, this research looks to understand ...[the] extent do unfavorable HOLC designations predict higher present-day exposure to climate-related health risks in New Haven neighborhoods? Results of this investigation reveal that unfavorable HOLC designations generally correlate to higher exposure to climate-related health risks. Land surface temperature values are higher by an average of 1.8°C in redlined neighborhoods than in surrounding non-redlined areas, and ...a quantitative measure of green space, is lower by 0.108. Pollution levels are not clearly correlated. It is necessary to understand historical forces driving modern climate risk disparities to...enact policies to mitigate such adverse effects.
In this thesis, I present a geospatial modeling approach to understand the climatological potential for the terrestrial storage of woody biomass via burial under evapotranspiration (ET) covers in the Western US. Given the 21st century wildfire crisis, forest managers are implementing mechanical thinning to remove low-value woody biomass at unprecedented scales. Terrestrial storage of biomass (TSB) in the form of biomass burial represents a potential opportunity to durably store this photosynthetically-captured carbon.

Soil water balance is critical to understand the potential for successful biomass burial. In the first section of this thesis, I develop an applied water model to temporally account for when snowfall reaches the water column and then use this applied water product with actual evapotranspiration (AET) to geospatially quantify water balance for 2001-2020 on a 1 km by 1 km scale. From this water balance, we calculate how much water would need to be stored in a monolithic soil cover to prevent the percolation of water assuming a potentially infinite water storage reservoir and then convert this required water storage to soil cover thickness.

This analysis indicates that there are regions in the Western US that have soil water balance conditions conducive to woody biomass burial from a macroclimate perspective. In the second section of this thesis, I utilize the latest CMIP6 climate modeling under two emissions scenarios, SSP2-4.5 an SSP5-8.5, to understand how the potential for biomass burial is projected to change throughout the 21st century geospatially with a 0.25º by 0.25º resolution.
This project undertakes a comprehensive cradle to gate techno-economic analysis of autothermal reforming (ATR) of glycerol derived from biodiesel production, evaluating its potential as a sustainable hydrogen production method. Our analysis includes a comparison with other hydrogen producing technologies such as Supercritical Water Reforming (SCWR), Anion Exchange Membrane (AEM) Water Electrolysis and the conventional Steam Methane Reforming (SMR).

...ATR emerges as the superior technology based on criteria such as the production cost, technology readiness, sustainability and environmental impact. Based on the [Pugh] decision matrix, the proposed ATR plant, designed with Aspen HYSYS, is integrated with a biodiesel production facility with a capacity of 174.8 ktons/yr of biodiesel and 17.48 ktons/yr of glycerol. The glycerol, assumed to be pure, serves as the primary feedstock. The plant aims for optimal hydrogen yield determined through analysis over its 25-year service life. Located in Texas, the plant benefits from low labor and electricity costs, operating 8000 annually.

Our economic viability and process optimization show that the plant can produce 2.4 million kilograms of hydrogen annually at a levelized cost of $4.50 to $7.80 per kilogram. In comparison, SMR achieves a lower cost range of $1.30 to $1.50 per kilogram. Although ATR is less efficient than SMR in cost terms, its integration with biodiesel production, simplicity and ability for scalability present significant competitive advantages...

Its environmental and sustainability benefits, alongside its ability to scale and simplicity, could make it a viable alternative in the ever-evolving field of hydrogen production technologies.
Examining the Effects of Precipitation Variation on Political Behavior in India

Daevan Mangalmurti ‘24

Trumbull | Ethics, Politics & Economics; South Asian Studies

Changes in the environment have the potential to produce political changes. But weather variation, natural disasters, and long-term climate change do not lead to uniform changes in political behavior. Scholars have found that in different social and institutional contexts, environmental phenomena may have wildly divergent effects (Gagliarducci et al., 2019; Hai and Perlman, 2022; Hazlett and Mildenberger, 2020; Liao and Ruiz Junco, 2022; Peterson, 2021). It is not yet clear, in particular, whether and how intensifying environmental volatility will force changes in both politicians’ behavior and prevailing institutional contexts.

In this thesis, I seek to understand whether environmental phenomena significantly affect politicians’ activity and incentives. I examine the effects of one kind of environmental change—average weather variation, indicated by precipitation—on two kinds of political behavior: the quality of representation offered by elected officials, and electoral behavior by incumbent politicians. Leveraging a unique Indian government scheme that offers insight into politicians’ preferences, I design a study that analyzes how agents respond to political incentives and economic incentives in the context of exogenous environmental constraints. In keeping with an interdisciplinary approach to this question, I also discuss the normative consequences of the success or failure of substantive representation by elected representatives and evaluate ways in which institutions may lead politicians to act in non-optimal ways...

The contribution of this research to the literature is to demonstrate that, for MPLADS, there is no real effect of weather on either the use of the program or its electoral consequences.

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↑ Surplus Precipitation Frequency During Parliamentary Terms and MPLADS Projects in Year t. Models 1-4 use environmentally-coded expenditure as the dependent variable. Models 5-8 use environmentally-coded project counts as the dependent variable. FE stands for fixed effects. Standard errors are clustered at the constituency level.
There is a critical need to develop precise monitoring, reporting, and verification (MRV) practices for carbon removal strategies such as enhanced mineral weathering (EMW). To help address current gaps, basalt and steel slag were applied to corn-soybean rotation plots at Carleton College in Minnesota as part of an ongoing EMW trial. Concentrations of mobile (Na, Mg, Ca) and immobile (Ti, Th) elements changed heterogeneously in the control, basalt-amended, and slag-amended plots. The TiCAT framework method was used to compare mobile and immobile elemental concentrations from pre- and post-feedstock amendment soil samples; elemental values fell outside of the anticipated range and carbon dioxide removal (CDR) rates could not be accurately calculated. This investigation concludes that baseline soil samples were not collected at a great enough spatial granularity, leading to irregularities in collected data.

The second part of this study evaluates the number of soil samples required to capture natural spatial soil elemental variation. A statistical simulation comparing the number of samples averaged to the deviation from the true sample set mean was run on soil sample sets from Haliburton Forest in Ontario and Carleton College in Minnesota. This analysis concluded that the sampling practices used to collect both sample sets insufficiently captured spatial variation in baseline soils. Simulations suggest that the original Minnesota EMW sample set size of 12 soil samples should be increased to 30 samples during both baseline and post-feedstock amendment sampling. By increasing confidence in soil elemental values, researchers can more accurately constrain CDR rates to develop clear MRV approaches.
This capstone addresses the profound challenge of transitioning Japan’s energy system to net-zero by 2050. The review covers many factors, including current energy sources and uses, existing and planned projects, general industry trends, and more. Building on the Kaya Identity for a comprehensive yet intuitive approach, the study examines Japan’s current and historical energy usage, demographic trends, economic trends, emissions data, and technological innovations in the context of energy transition.

Key findings from the research suggest that Japan’s transition to a low-carbon economy is encumbered by many socio-economic and political challenges but remains feasible with strategic interventions addressing key vulnerabilities spanning across the economy, cultural perceptions, international political commitments, industry incentives, and more. The potential for nuclear energy’s role in achieving net-zero emissions is contentious yet crucial, given its ability to provide stable, low-carbon power, but the success of this transition also hinges on significantly boosting renewable energy sources. In particular, several areas such as offshore wind and electric vehicle adoption are underutilized. The economic analysis indicates that while the transition may entail substantial upfront costs, it could yield long-term benefits through reduced reliance on imported fuels, improved energy security, and leadership in green technology.

The analysis suggests that an integrated approach which addresses key vulnerabilities by combining energy security considerations, economic incentives, effective public communication, industry-led initiatives, technological advancement, and international cooperation, is required for Japan to reach its 2050 goals.
Integrating Artificial Intelligence (AI) into smart grid management is an important technological milestone to achieve to revolutionize how electricity is managed and distributed. Modern energy systems are facing novel and complex challenges. As the need for sustainable energy continues to grow, there is a need to transform traditional energy grids in order to account for the rise of renewable energy, new energy storage technologies, and the use of electric vehicles. AI technologies, such as artificial neural networks, are crucial for electrical grids’ transformation into intelligent networks with the ability to predict maintenance needs and make real-time decisions. This paper delves into the journey of AI integration into smart energy grids, from the early days of its development to its current role as backbone of modern smart grids. In turn, we will look forward into the future in order to understand the potential impact on society this technology could have. ...

Integration of AI, particularly through Artificial Neural Networks (ANNs), into smart grid management is setting the stage for a transformative era in how electricity is managed and distributed. This technological evolution addresses the needs of a modern complex energy system, especially with the integration of renewable energy. By using the capabilities of ANNs, smart grids are evolving into more intelligent networks that can anticipate maintenance needs and adapt in real-time to the dynamic demands of energy consumption.

Continued development and integration of AI technologies are poised to make significant impacts on society such as energy costs for consumers, improving the reliability of energy supply, and supporting the shift towards sustainable energy systems.
Halide perovskites are a class of crystal structures that have interesting properties for solar PV cells because of their easy fabrication, potential high efficiency, and promising applications in other devices such as LEDs and photodetectors.

Semiconductors, however, require doping—the introduction of impurities or defects into the regular, pure crystal structure to tune electrical properties—which is challenging with halide perovskites due to compensation from intrinsic defects. Doping by charge transfer has been proposed as an alternative to traditional doping.

The molecule 2,3,5,6-Tetrafluoro-tetracyanoquinodimethane—F4TCNQ, for short—has been demonstrated as suitable for p–type doping of halide perovskite MAPb$_{0.5}$Sn$_{0.5}$I$_3$ by charge transfer. This project studies variations in F4TCNQ doping by changing the morphology of the deposition film and studying the resulting electrical properties by the Hall effect. In addition, the same technique is used to study the possibility of designing a better dopant using the related molecule, F6TCNNQ.

AC Hall-effect measurements on thin films of MAPb$_{0.5}$Sn$_{0.5}$I$_3$ with and without dopants showed that

- F4TCNQ doubled the grain size and F6TCNNQ produced pinholes in the deposited semiconductor thin films.
- F4TCNQ does p-dope MAPb$_{0.5}$Sn$_{0.5}$I$_3$, though less than previously observed.
- F6TCNNQ does not yet effectively p-dope MAPb$_{0.5}$Sn$_{0.5}$I$_3$.

Next steps were proposed to modify the film deposition conditions to form uniform films with F6TCNNQ for further testing.
Class of 2024 Yale Energy Scholars
Class of 2024 Yale Energy Scholars | Majors

- Applied Physics
- Architecture
- Chemical Engineering
- Chemistry
- Computer Science
- Earth & Planetary Sciences
- Engineering Science
- Engineering Science-Chemical
- Environmental Engineering
- Environmental Studies
- Ethics, Politics & Economics
- Global Affairs
- History
- Political Science
- South Asian Studies
- Statistics & Data Science
- Master of Music (Violin)
To the Yale Energy Studies Scholars in the Class of 2024

You are the 11th class of Yale Energy Scholars.

Yale Climate & Energy Institute, where the program started, awarded 8 unofficial Energy Studies certificates to the Class of 2014. This year’s class of 37 graduates, receiving official Energy Studies Interdisciplinary Certificates from Yale College, pushes the number to well over 300. So, you are already part of a long tradition, and I hope that when you come back for your 5th, 10th, 25th, or 50th reunion (mine will be in two weeks!), you will be able to see the tradition still growing and will, in the meantime, have been able to connect with the next generation of Yale Energy Scholars in the same way that previous generations of Yale Alumni in Energy have connected with you.

Every year as I go through your senior projects to prepare this slideshow, I am surprised, amazed, and astonished by the diversity of topics, by the level of thought and detail, by the creativity, by the energy that has gone into the work you do to think up, design, and execute these projects over the course of senior year, and in many cases longer than that. Every year I think, Surely last year was the best. This group is good, very good. But it’s not possible to beat the work of last year’s class. Equal maybe, but not be better. And so far, at least, every year I’ve been wrong, very wrong. (Of course, that’s not what I’ll tell previous classes when they come back for reunions. But that’s just between you and me for now.) You’ve all done outstanding work.

Still, I have to say that the slide I’m most eager to prepare each year is the previous slide, the one showing the distribution of majors and degrees. Look at what you’ve achieved as the 2024 Class of Yale Energy Scholars, outside of your capstones:

39 B.A. or B.S. degrees from Yale College and 1 Master of Music (Violin) (that’s a first)
18 different Yale University departments and majors represented, the highest diversity of majors in the program’s history.

EVST holds the top slot this year with 8 majors. Followed by:
EP&E and ECON with 5 each. Look also at:
Engineering Science, with 4 total, counting Chemical Engineering and Environmental Engineering,
History with 3, and Architecture returning strongly this year with 2 Yale Energy Scholars.

With the Class of 2024, there are now 313 Yale Energy Scholars, holding 37 different Yale College and Graduate School degrees. Members from this year’s class have won several department and university awards. You’ll hear about some of them at Class Day.

Finally, a toast (it’s the same one every year):
To the Yale Energy Scholars in the Class of 2024: May you never lack the energy to pursue your dreams.
And, May your dreams have the power to change the world. But especially, May your dreams have the power to change your world: The people, places, and things nearest and dearest to you.

— Michael Oristaglio, Director Energy Studies