

Making Cornell a Global Leader in Energy Research, Education, and Translation

The Big Idea

Three of the biggest challenges facing humanity as the world's population quickly approaches eight billion are having enough food, enough water, and enough energy to sustainably support a growing population. Any careful examination of the food and water systems of the world makes it clear that they rely on the availability of energy in direct and indirect ways. Therefore, finding ways to make energy systems markedly cleaner and more efficient is a necessary part of ensuring plentiful food and clean water for the future. The three are inextricably tied together.

Increasing energy resources, recovery and reuse of water and waste, efficient land use, and addressing myriad environmental impacts from the air to the ocean require multi-faceted solutions that will emerge from many areas of expertise, but success will only come from leaders that understand and can manage complex systems who are equipped to build solutions across scales. Engineers, by their training, possess systems-level thinking and are prepared to lead in this way. Cornell engineers have been pioneering the innovative and integrated solutions that are reducing dependence on non-renewable energy sources and promoting sustainable prosperity for all. But engineers cannot do it alone: social scientists, entrepreneurs, policy makers, educators, and public leaders must be part of implementing solutions.

This kind of broad cooperation does not emerge spontaneously. A university system like Cornell's is a perfect microcosm for developing solutions and implementing changes within a large, complex, diverse system of people who must embrace any energy solution across technological and behavioral lines. Cornell is the best-positioned university in the world to demonstrate such success because of its unique and diverse locations and populations (both urban and rural), our collaborative and service-oriented ethos due to our land-grant status, and our proven competency in taking global challenges and solving them at local scale and then sharing that success far and wide to influence change on the global scale.

Problems related to energy are complex. Meaningfully sustainable solutions demand systems approaches, which require expertise that typically falls outside conventional disciplinary boundaries and beyond the capabilities of individual researchers. **Cornell's Energy Systems Institute (CESI)** brings together researchers working on components of these problems to accelerate discovery and commercialization of materials, devices, and intelligent systems designs required to lower costs, improve performance, and reduce humanity's carbon footprint. In just the way that the Cornell Atkinson Center for Sustainability has quickly become a well-respected hub for sustainability research at Cornell, the Cornell Energy Systems Institute is positioned (with the necessary infusion of resources) to be the University's innovation hub for next-generation, cleaner, more efficient energy systems and technologies.

An important example is Cornell's commitment to carbon neutrality by 2035. Reaching this carbon neutrality goal will require expertise from across the campus, but critical leadership in framing this plan comes from within CESI. The College of Engineering's clear and vital role in attaining this goal will be technology innovation and development—which is already a strength of CESI. However, to deploy any successful technology to achieve carbon neutrality on our campus will also require new educational practices that focus on practical implementation of technology into a complex system and studies of human response to that implementation. Cornell has a long history as a “living laboratory” that does this better than anywhere else in the world. Cornell researchers have long used Cornell's buildings, utilities, and transit systems as a test-bed, or living laboratory, for conceiving new ideas and approaches, testing and refining them at scale, and then broadly sharing what is learned so that solutions can be adopted by others. For example, the highly-successful Lake Source Cooling project has resulted in an 85% reduction in cooling-associated energy use since its completion in 2000. The proposed Earth Source Heat project

currently underway could be just as revolutionary for our campus and another example of an integrated energy solution that can be shared far and wide to inspire other communities to capitalize on their natural resources to create a sustainable solution.

With CESI at the forefront, the campus as a living laboratory, and our community ready to take bold steps together to demonstrate energy solutions, Cornell Engineering is uniquely positioned to be a world leader in finding and implementing solutions to the world's energy challenges. In doing so, the College can have a direct and meaningful impact on crucial food, water, and climate challenges. The focus of future investments is contained in the following strategic initiatives.

Strategic Initiatives

- 1) **Hire a global leader in energy systems to direct the Cornell Energy Systems Institute:** This leader will expand Cornell's capacity and impact by securing funding and center-level grants to grow the Institute and be a key person to connect synergistically with other leaders across campus. With this hire, the College of Engineering will cement its leadership on campus in *technology innovations and entrepreneurship* that complement the leadership of the College of Agriculture and Life Sciences and the College of Arts & Sciences in the areas of environment and sustainability, and humanities and science, respectively.
- 2) **Hire a cluster of faculty experts in strategic areas that support energy innovation:** These areas are critical to any energy solution that emerges: energy transformation, transport, recovery, and storage; data science and machine learning; complex systems and process optimization; decision analysis and design.
- 3) **Create a physical nexus for CESI that serves as the energy systems research and education center of the College and connection hub for the rest of the campus and world for energy systems work:** Finding energy solutions requires people coming together to communicate, innovate, work and learn. An inspiring facility that catalyzes these activities can have a huge influence on success. Silicon Valley knows this, and Duffield Hall on our campus is a successful example in nanotechnology. Now we need to create an innovation center for Energy Systems. Our ambition is to create this state-of-the-art energy test bed for technology development, evaluation, translation, and education within Olin Hall, capitalizing on its centralized location on campus and proximity to the social sciences, humanities, business and law schools.
- 4) **Create programs for Energy Entrepreneur Fellows and Energy Project Teams:** Successful student inventors will take their technology innovations from concept to implementation, learning how to translate their innovations into practical solutions. Continual progression of experiential learning and evaluation through design, build, test, evaluate cycles are the backbone of the *living laboratory* philosophy. This approach to creative design and innovation is what student inventors will embrace in programs that will deliver the skills necessary to become successful entrepreneurs and launch startups, at any level from undergraduate through post graduate researchers.
- 5) **Create partnerships across campus to develop new programs that integrate engineering with the humanities and social sciences:** These partnerships will promote social entrepreneurship, by informing students about energy policy and humanitarian affairs related to energy equity and impacts of climate change, and preparing them to innovate and lead the changes necessary for a sustainable energy future. We will produce well-rounded experts uniquely knowledgeable across the

energy/climate/human interface by embracing our Ivy campus colleagues in a unique program that develops the student leaders of tomorrow who are equipped to lead from the local to the global scale.

Cornell has matchless strengths and advantages that position us for success

Any effort to make Cornell a global leader in energy research, education, and translation would make no sense if the College of Engineering and the broader University were not already well-positioned to assume this role. In fact, it is our very strengths and inherent advantages that make this an obvious area for investment and development to push Cornell Engineering to the forefront as a global leader in defining energy solutions.

Cornell is ready to contribute to a sustainable water-energy-food nexus that no longer impacts Earth's climate, but it is a challenge that can only be successful with the massive coordination and integration of solutions that span three key areas:

- 1) **Engineering and technology innovations** are the only way to eventually eliminate dependence on carbon sources for our energy requirements and advance climate science to reverse the damage done
- 2) **Connection with the humanities** is necessary to promote changes in human behavior through social science, economics, and policies that shift attitudes about energy and water use
- 3) **Environmental science and agricultural practices** must develop sustainable methods that meet the energy, water, and food demands of a growing human population and preserve species diversity on Earth

Cornell University is especially well positioned to capitalize on the success of the convergence of these areas because since its inception, Cornell faculty have worked across colleges and found common ground upon which impactful research has emerged for over 150 years. Cornell is the **only Ivy League school with a land grant mission** that uniquely gives us comprehensive strengths in the sciences, engineering, humanities, and the agricultural sciences.

These designations also give us a globally recognized leadership identity as a member of the Ivy League, with the ethos of service built into our core from the land-grant mission. We produce authentic servant-leaders who, as educators to the world, will have multiplicative impacts. Major university investments have built strong interdisciplinary traditions, including the establishment of the Atkinson Center for Sustainability, a new Cornell School of Public Policy, and the Cornell Center for Social Sciences that Cornell engineers routinely engage.

Within the College of Engineering, the **Cornell Energy Systems Institute CESI** is a critical component poised to lead the technological innovations across the university that complement the sustainability and social science elements from other colleges, centers, and schools. With a larger investment in this institute and its people and programs, it will be a crucial partner for the achievement of Cornell's carbon neutrality by 2035, become globally recognized for excellence in energy solution innovation, and be a beacon for teaching others how to develop integrated energy solutions.

Importantly, one of the revolutions in engineering research over the past 50 years has been the growing awareness of the need to take a systems approach to solving complex problems. It is now widely acknowledged that challenging technical problems do not exist in isolation; they are part of a larger, connected system. Finding a sustainable water-energy-food nexus is the greatest systems engineering challenge of our time. Any proposed solutions in any one area, must take into account the impact across the larger nexus and thus requires a different way of problem-solving. This "systems thinking" is second nature

to Cornell Engineering faculty. In fact, Cornell Engineering is home to one of the **top-ranked Systems Engineering programs** in the world.

Cornell has an intrepid scientific environment that stimulates bold ideas and actions that position us for global recognition. An important example is when Cornell undertook Lake Source Cooling of the campus. This is one of the most significant environmental initiatives ever undertaken by an American university and is now a demonstrable success. Cornell recently committed to another bold experiment in Earth Source Heating of the campus, commencing this year. This project is a new opportunity for students to see innovation in action and work together with the facilities staff, faculty investigators, and other student researchers using the project as a vehicle to learn as it comes to life. With robust programs in biomass, solar, and wind, and plans to expand into green hydrogen, Cornell's energy and sustainability portfolio is second to none and thus offers opportunities for pioneering technological advancement and educational experiences for students available nowhere else.

Learning by doing: the 'Living Lab' approach is a unique Cornell philosophy

Going back to the days of Ezra Cornell and the founding of the University, teaching has always been a primary focus at Cornell. Students come to Cornell not only to learn what is already known, but to have a hand in creating new knowledge. Cornell fosters learning through innovation, as evidenced by our ranking #6 in producing venture capital backed startup founders and #10 in generating university patents. But the key to this success is Cornell's emphasis on building a solid foundation of fundamental knowledge in our students, from which innovation and creativity can be cultivated.

As clean, green energy demands increase, the College is well positioned for impact because of our natural strengths across our engineering disciplines in the fundamental science necessary for energy management: chemical kinetics, thermodynamics, transport processes, and systems thinking. Our faculty are leaders in complex fluids and polymers, geothermal engineering, biomass conversion, solar materials development, batteries and energy storage, and systems analysis. Our engineers understand how systems work across scales and how to scale up what is learned at a pilot scale to industrial scale. The College is already recognized for developing pioneering technologies that are shifting society away from environmentally damaging, inefficient, non-renewable energy systems to cleaner, more sustainable alternatives that are scalable. Cornell's approach embraces a **"living laboratory" philosophy** to enable an active learning environment for students working with operating energy systems at scale. Cornell's living laboratory allows students, faculty, and facilities staff to evaluate more sustainable energy options in a unique manner: by using Cornell's buildings, utilities, people, and transit systems as a test-bed for conceiving new ideas and approaches, testing and refining them at scale and then broadly sharing what we learn, solutions can be adopted by others for maximum impact.

Today's students want to learn engineering while solving real problems and seeing those solutions have impact now. By **transforming Olin Hall into a multi-dimensional living laboratory for interdisciplinary, collaborative energy research and education**, students can design a technology or model a process, test it in Olin Hall's building system, evaluate it, and learn in real time during this process. Well-resourced, innovation hubs in a transformed Olin Hall will provide students with dedicated space for innovation and will allow Cornell to tap into a new source for tomorrow's discoveries: student inventors. The proposed Olin Hall test-bed facility will enable the integration of the College's research and teaching missions, yielding both scientific solutions and leaders of tomorrow in the energy arena. We will guide student metamorphosis into creative, agile, adaptable leaders, team members, and entrepreneurs by developing: i) human-centered research facilities that require real-time, hands-on engagement with technology and ii) human-centered professional development in entrepreneurship, business acumen,

technology transfer, and technology adoption. **Energy Entrepreneur Fellows** will take their technology innovations from concept to implementation in Olin Hall and study how it affects the entire building's energy system. Continual progression of experiential learning and evaluation through design, build, test, learn cycles are the backbone of the living lab philosophy and the approach to creative design we aim to teach our students and student entrepreneurs.

Additionally, most faculty in the College include undergraduate students in their research teams. With more resources and a growing reputation for world-changing research, the Cornell Energy Systems Institute and its member faculty could prepare these undergraduates to step into their roles as the next generation of leading-edge sustainable energy researchers and innovators.

With the philosophy of “living laboratory” extending to the whole campus, **One Cornell** is a critical proving ground for technologies that will enable not just campus carbon neutrality by 2035, but will become an exemplar for others to do the same at scale and then to scale up to cities, states, nations, and beyond. This bold vision requires leadership from our faculty, and the College faculty routinely and demonstrably translate successful technological solutions from this campus to the global stage. A recent example is the pioneering work of Peter Frazier and his team from ORIE who developed the modeling that critically informed testing, policy, and safety measures for our campus during COVID-19 and became globally recognized as an archetype for pandemic management. This kind of success can be replicated in the water-energy-food nexus with continued investment in faculty hiring, graduate student support, programmatic investments in our undergraduates, and necessary infrastructure expansions to create this new capacity for impact.

Call to Act and Invest

With the wide-ranging expertise of researchers in the College of Engineering, the College of Agriculture and Life Sciences, the College of Arts and Sciences, and Cornell Tech; the proven track record of the Cornell Atkinson Center for Sustainability; the tradition of Cornell's campus as a living laboratory; and the leadership of the Cornell Energy Systems Institute, the University is uniquely positioned to be a world leader in finding and implementing sustainable solutions to the world's interrelated food, water, climate, health and energy challenges.

For our part in solving the energy and climate crises, we intend to be bold and ambitious, to create key partnerships across the university necessary for success, and to serve as the example from which others can learn. Ultimately, increasing investment in the Cornell Energy Systems Institute and giving it a permanent home in a renovated Olin Hall will catalyze innovation and serve as the organizational center of a Living Lab for Energy Systems work in the College of Engineering. This investment will ensure Cornell earns its place at the forefront of energy innovation and is known for excellence in research that frees us from carbon-based energy sources. It will build from Cornell's existing ability to analyze and manage complex systems and foster the production of the next generation of student leaders who will ensure solutions are inclusive, equitable, and sustainable. Investments in CESI, critical faculty partners, associated disciplines, and facilities is an integral part of the College of Engineering's strategic plan to foster global leadership and innovation in energy research, education, and translation to real world solutions that benefit us all.