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### ABOUT STANFORD UNIVERSITY’S PRECOURT INSTITUTE FOR ENERGY

Through collaborations across campus, Stanford University’s Precourt Institute for Energy fosters and supports the Stanford energy community. The institute and its programs fund research that has the potential to solve today’s toughest energy challenges and help transform the world’s energy systems.

Stanford students can discover energy through the institute’s Explore Energy program, including experiential courses, internships, entrepreneurial activities and a one-week orientation for incoming graduate students interested in energy.

The Precourt Institute works with industry leaders, entrepreneurs and policy makers for the broad deployment of solutions. It also engages a wide range of stakeholders at events like the Global Energy Forum.

### PRECOURT INSTITUTE CENTERS AND PROGRAMS

- Bits & Watts Initiative
- Energy Modeling Forum
- Explore Energy
- Mexico Clean Economy 2050
- Stanford Energy Corporate Affiliates
- Stanford Environmental & Energy Policy Analysis Center
- Stanford Natural Gas Initiative
- StorageX Initiative
- Strategic Energy Alliance
- Sustainable Finance Initiative
- TomKat Center for Sustainable Energy
Before I became director of Stanford’s Precourt Institute for Energy at the start of 2021, I knew the institute was amazing. Then I found out how much impact it really has in research, education and engaging with the world. As you read this report, I hope you feel the same sense of pride.

First, I must thank my predecessors, former co-directors Sally Benson and Arun Majumdar, and the institute’s founding director Franklin (“Lynn”) Orr. They built a dynamic organization that contributes much to realizing the vision of sustainable, affordable and secure energy for all people. Sally, Arun and Lynn still contribute to the work of the institute and are at my side whenever I need them, for which I and the Precourt team are extremely grateful.

Sadly though, we are now without one of our leaders. The Honorable George Shultz, chairman of the institute’s advisory council, died on Feb. 6. (See page 17.) Secretary Shultz was dedicated to fighting climate change. Our vision for energy is based on his: Advances in energy must improve our environment, economy and security. Secretary Shultz also chaired the advisory board of the MIT Energy Initiative. He created many collaborations between the two universities on energy, like the successful appeal to Congress to maintain funding for fundamental energy research and the book *Game Changers: Energy on the Move*. Thanks to Secretary Shultz, such Stanford/MIT collaborations continue today, like the November 2021 study on extending operations of the Diablo Canyon nuclear power plant. George’s contributions to realizing a brighter energy future will live on for a long time.

We have much to celebrate from this past year and much to look forward to. We welcome two new members to our advisory council: John Hennessy, former president of Stanford University and director of the Knight-Hennessy Scholars Program; and Eric Yuan, CEO and founder of Zoom Video Communications. John and Eric’s counsel will be invaluable to me. Also, our Bits & Watts initiative is now led by faculty members Inês Azevedo and Ram Rajagopal, both experts on building a smarter electricity system. And, thanks to several key partners across campus, we launched a new research program this year – Precourt Pioneering Projects – to fill a gap in funding for great new ideas moving to the next stage in development. (See page 3.) Finally, many students, faculty and staff were excited by the launch of our Explore Energy education program. (See page 8.)

Looking ahead, the Precourt Institute will become an integral part of Stanford’s new school focused on climate and sustainability, starting in September 2022. The institute can contribute much to the success of the new school, and the new school will enhance the institute’s contributions to the energy transition. I am also very excited about the return of Stanford Global Energy Forum in May 2022. (See page 11.)

Thank you for all your contributions to the institute and the broader mission. As this report shows, the world is transitioning to sustainable, affordable, secure energy for all.

Yi Cui
Director, Precourt Institute for Energy
Professor, Materials Science & Engineering, and Photon Science (SLAC)
The past fiscal year – September 1, 2020 through August 31, 2021 – produced important research advances among the Precourt Institute’s initiatives, research centers and programs. Pathways for India to develop a clean energy sector were illuminated, as were the possibilities for carbon capture and storage in California. Also, the Precourt Institute established a new research funding program for Stanford faculty in energy.

**Rechargeable batteries with six times more charge**

An international team of researchers led by Stanford developed rechargeable batteries that can store up to six times more charge than those commercially available today. The advance, detailed in the *August 25 issue of Nature*, puts battery researchers one step closer toward achieving two top goals of their field: creating a high-performance rechargeable battery that could enable cellphones to be charged weekly instead of daily, and electric vehicles that can travel six times farther before recharging.

The new alkali metal-chlorine batteries were developed by researchers led by Stanford chemistry professor Hongjie Dai and doctoral candidate Guanzhou Zhu. The researchers envision their batteries one day being used in situations where frequent recharging is not practical, such as in satellites or remote sensors. The working prototype they developed could be used in small everyday electronics like hearing aids and remote controls. For consumer electronics and electric vehicles, more work remains to engineer the battery structure, increase the energy density, scale up the batteries and increase the number of cycles.

This research was supported by a Bits & Watts graduate student fellowship.
$8.3 million for early-stage research with big potential

The Precourt Institute expanded support for early-stage research at Stanford in 2021 with the addition of Precourt Pioneering Projects (PPP) and the Strategic Energy Research Consortium (SERC). Together with seed grants that the institute began making annually in 2010, the new programs provide a path for Stanford faculty, especially in interdisciplinary research teams, to test and develop high risk/high reward ideas in energy.

PPP awards are made every quarter on one topic. The two-year grants for $400,000 to $600,000 are meant to bridge the support gap between seed grants of up to $200,000 for two years and SERC’s three-year grants for up to $1.5 million.

The topic of PPP’s first grants is using artificial intelligence to make energy systems more sustainable, affordable, resilient and fair to all socioeconomic groups. Two proposals were funded in June by the Precourt Institute in partnership with the Stanford Institute for Human-Centered Artificial Intelligence, SLAC National Accelerator Laboratory, and the Bits & Watts Initiative. One project, led by associate professor Inês Azevedo, is building a platform centered on how policies and people shape the needed transition to sustainable and fair energy systems. The other project, led by associate professor Ram Rajagopal, is creating open-source tools to assess, forecast and plan for a human-centered infrastructure system with a particular focus on electricity.

In September, PPP in partnership with Stanford Woods Institute for the Environment funded three new projects on reinventing plastics and their lifecycle of use. One project, led by professor Joseph DeSimone, is developing chemistries and three-dimensional printing techniques to transform how plastic parts in cars are designed, manufactured and recycled. Another, led by professor Zhenan Bao, is exploring a new class of plastics to enable upcycling of plastics and reducing waste. The third project, led by assistant professor Dan Congreve, is developing a reusable 3D printing resin that can be printed, bulk erased and reprinted over numerous cycles to slash waste.

The topics for the next three PPP grant cycles, all in fiscal year 2022, will be energy-efficient computing, carbon removal and hydrogen’s role in decarbonization.

In the spring, the Strategic Energy Alliance chose six research projects to fund under SERC, into which corporate members pool funds to be awarded at the discretion of the Precourt Institute’s leadership. SERC’s first round committed $5.1 million. The four technology projects cover passive cooling of buildings, semiconductors as electrocatalysts, low-carbon concrete and algae-based biofuels. The two policy and finance research projects explore climate-neutral gas utilities and global negative emissions portfolios.

The Precourt Institute and its Bits & Watts Initiative did not make new seed grants during fiscal year 2021, instead funding PPP in part. The institute’s StorageX Initiative made six seed grants for a total of $480,000. The projects focus on fast charging of lithium-ion and solid state batteries, improving the electrolyte-electrode interface in lithium-ion batteries, designing better recycling processes for batteries, and assessing the potential and value of used EV batteries for secondary uses.
CCS road map for California to achieve climate goals

Capturing and storing carbon dioxide can significantly help California meet its aggressive goals to combat climate change, according to a joint study that lays out a road map for the state and an example for other governments.

California aims to become carbon neutral by 2045. The October study by the Precourt Institute for Energy, the Stanford Center for Carbon Storage and former Secretary of Energy Ernest Moniz’s Energy Futures Initiative provides an action plan for policy makers detailing opportunities, challenges and solutions for carbon capture and storage in the state. The technology can rapidly reduce emissions from economically vital sectors in California that have few other near- or mid-term options to decarbonize, like the production of electricity and cement, and oil refining.

Adding CCS to some power plants fueled by natural gas could contribute significantly to California meeting its goals of 60 percent renewable generation and a 40 percent reduction in greenhouse gas emissions by 2030, the study found. CCS also would improve electric system reliability and provide employment opportunities for the existing energy workforce in new energy jobs that take advantage of their skills in refinery operations. New industries and jobs in the hydrogen economy, CO$_2$ removal and CO$_2$ utilization are also enabled by CCS technologies.

Making wastewater obsolete with circular water treatment

Once the bathwater is drained, the toilet flushed or the laundry done, few give a passing thought to the wastewater that leaves our homes, but that water is a mine of valuable chemicals. Chemicals like nitrogen, phosphorus and potassium make great fertilizers. Lithium can be used in lithium-ion batteries. And even pharmaceuticals could be recovered and reused.

In a January study, assistant professor Will Tarpeh and his postdoctoral scholar Xi Chen focused on the nitrogen cycle using selective materials and electrochemical processes for recovery. Ultimately, the study outlines the next thirty years of modular, selective, resource-efficient separations that will play a major role in enabling element-specific circular economies and redefining wastewater as a resource.

The research was supported by a StorageX Initiative seed grant.

How to power up battery manufacturing in India

By 2030, India plans to generate 40 percent of its electricity from renewable sources and have electric vehicles make up 30 percent of its automobile sales. To switch from coal-generated electricity, diesel and gasoline to renewable energy, India – like most countries – will require advanced battery technologies. Instead of buying billions of dollars’ worth of batteries abroad, India could develop its own battery industry with some government assistance and become a global producer of batteries, according to a December study published in the Journal of Energy Storage.

Researchers at the Precourt Institute’s Sustainable Finance Initiative recommended that India focus on battery manufacturing in the short term but build capacity for higher-value research and development for the long term. In addition, the government should help identify target markets and explore the use, possibly, of protectionist measures that give domestic companies an advantage over international competitors.

“Upstream processes tend to be more technology intensive. Understanding this can help Indian manufacturers find the right niche,” said Gireesh Shrimali, co-author of the study and a social science research scholar at the initiative.
Innovation and India’s Energy Future

The Precourt Institute partnered with ReNew Power, India’s largest independent power producer, to explore India’s needs and opportunities for innovation in building a sustainable energy system. In February 2020, Stanford researchers from the Bits & Watts Initiative, StorageX Initiative and the Sustainable Finance Initiative held roundtable discussions in India with executives from ReNew, as well as experts from Indian research institutions, government and civic organizations.

The purpose was to better understand the key factors, barriers and opportunities that impact India’s energy landscape, particularly in the power sector, clean energy finance and electrification of transportation. The group identified actions and collaborative projects where Stanford and the Silicon Valley innovation ecosystem can partner with stakeholders in India to play a positive and enabling role for India to achieve its goals and aspirations at speed and scale. The group published their findings, including identifying key opportunities for innovation, in a November 2020 report “Innovation and India’s Energy Future.”

Simple rates make electricity systems more efficient

Electric utilities in developed economies increasingly charge residential customers variable electricity prices depending on the time of day when the electricity is used. Consumers shifting demand from the evening peak to other times of the day lowers system costs, outages and pollution. Just two or three time periods captures most of the cost savings for an electricity system, according to a January study by Bits & Watts postdoctoral scholar Nicolas Astier.

Instead of dividing days into more time slots, rate designers can achieve much higher efficiency gains by instituting critical peak pricing, which allows utilities on a limited number of days to raise the price of electricity when power demand is expected to exceed supply, like during a heat wave. Charging high peak prices under rare contingencies may not be politically feasible, Astier acknowledges, but it’s a much better approach than complicating rates with zone-specific prices to reflect local supply shortages. Now back in France, Astier has been discussing his findings with the country’s Energy Regulatory Commission and researchers at France’s major power utility, Électricité de France.

Drawing fresh water from the atmosphere

Water vapor in the atmosphere is equivalent to about 15 percent of global rivers and lakes. This is why professors Juan Santiago and Kenneth Goodson see air as a viable resource for meeting humanity’s growing water needs.

Their research team demonstrated an efficient method for extracting water from air using a newer kind of material called metal-organic frameworks, in preliminary research supported by the TomKat Center for Sustainable Energy. They see the technology as a complement to electrical power plants that are in need of water for cooling towers. It could become a virtuous loop, as those same towers go on to produce warm air that could drive the water harvesting process.

“We basically take low-grade heat and turn it into freshwater,” said Santiago. “Other agencies wouldn’t have touched it. The research was too high risk,” he added, explaining that their idea was too much of a gamble for traditional research grants.
Effects of North American energy trade and integration

More integrated North American fuel and power markets will drive energy decisions not only within Canada, Mexico and the United States, but also internationally. To better inform decision makers, Stanford’s Energy Modeling Forum published a series of 13 studies as a special issue of the journal *Energy Policy*. Outlooks for production, consumption and trade of oil, natural gas, coal, petroleum products and electricity over the next 30 years vary quite a bit based on assumptions, such as carbon policies and natural gas prices, in the various models.

Nevertheless, the models agree on some takeaway lessons:

- Among the United States, Canada and Mexico, cross-border trade for natural gas, electricity and crude oil likely will rise.
- North America can play a more important role in world oil and gas markets if oil and gas prices increase from current levels.
- The outlook for coal is a modest to sharp decline, which would suffer the most from carbon taxes, lower natural gas prices, and rising supplies of wind and solar power.

Three new research initiatives ahead

The Precourt Institute and its partners made progress on three new research initiatives in fiscal year 2021. The Hydrogen Focus Group – developed by Stanford Energy Corporate Affiliates, the Natural Gas Initiative, and the SUNCAT Center for Interface Science & Catalysis – is planned to become a full-fledged initiative in spring 2022. Its leaders published “Zero Emission Transit Bus Technology Analysis” in June. The focus group organized a workshop on how to decarbonize trucks, trains, ships and planes with experts from academia, industry and government in April. The workshop resulted in the 40-page “Decarbonizing Heavy-Duty Transportation” brief in August.

The Precourt Institute and Stanford Woods Institute for the Environment continued to develop an initiative on carbon removal. The initiative’s developers worked with the Precourt Institute’s main sponsored research program, Strategic Energy Alliance, to organize two workshops with participants from academia, industry, government and nongovernmental organizations during fiscal year 2021. Both workshops identified research opportunities in global carbon management. The first, in September 2020, focused on natural climate solutions. The second, held in June 2020, focused on engineered and hybrid solutions. The Precourt and Woods institutes expect to launch an initiative on carbon removal in fiscal year 2022.

A third initiative, also expected to launch in fiscal year 2022, will support the net-zero commitments of corporations and other entities. The initiative will connect each member company’s climate pledge challenges with Stanford research, education and convening capabilities. The resulting knowledge, standards and best practices can be utilized by all members and – through published research – other organizations, so that not every company, campus and city has to reinvent the net-zero wheel.
For Stanford students interested in energy, the Precourt Institute and its programs provide courses, internships, entrepreneurship training, guidance, and an annual orientation week for 125 new graduate students interested in energy. During fiscal year 2021, despite most activities taking place online, all the programs continued to deliver on the institute’s educational mission: helping to develop a generation of experts and energy-literate people for the energy transition.

From labs to sustainability startups

The TomKat Center for Sustainable Energy’s Innovation Transfer Program trains Stanford students to advance sustainability technologies undertaken or originating at Stanford toward commercialization. During fiscal year 2021, the amount of external funding for past awardees mushroomed from $260 million to $1.03 billion, due largely to five acquisitions. Grants made since the program’s start in fall 2013 through August 2021 total $5.1 million.

The program is educational. All applicants must have a committed faculty advisor. Grants are awarded to develop prototypes, refine business plans, and conduct customer trials and market research.

Brian Bartholomeusz, the program’s executive director, connects the leaders of funded projects with industry and finance mentors for further entrepreneurship training.

Among past awardees, Cuberg (2015), which developed an ultra-light lithium metal battery, was acquired by battery manufacturer Northvolt in spring 2021. Aurora Solar (2013) software is used to design more than 8,000 solar projects a week and is scaling up with a recent $250 million investment round, resulting in a $2 billion valuation. ClearMetal (2015) was acquired by Project44.
Stanford students’ concierge for everything energy

Explore Energy is the Precourt Institute’s student engagement and education program across all Stanford’s schools, including the new school focused on climate and sustainability. The program increases energy literacy, experiential learning, mentoring and networking at Stanford. The Explore Energy program includes Energy@Stanford & SLAC, Shultz Energy Fellowships, the Summer Undergraduate Program on Energy Research, Understand Energy, Stanford Climate Ventures, Stanford Energy Seminar and the Explore Energy student dorm.

In spring 2021, Explore Energy’s application for a new academic theme dorm was accepted. It will open in fall 2022.

In fall 2020, the Explore Energy team recruited Amory Lovins and Holmes Hummel to join Stanford as Precourt energy scholars. Lovins, Hummel and Anthony Kinslow, a lecturer in the Department of Civil & Environmental Engineering, taught three new courses at Stanford: Applied Hope, which teaches whole-systems thinking to meet energy and environmental challenges; Racial Equity in Energy; and Quest for an Inclusive Clean Energy Economy. Lovins and Hummel also continue to teach the Extreme Energy Efficiency course.

Explore Energy staff continue to personalize tools and experiences for Stanford students, building network connections and community. They restructured the education section of the energy.stanford.edu website to provide a one-stop resource for energy opportunities. The program’s managing director Diana Gragg filled out the Explore Energy team with program managers Bianca Dilip Patel and Wahila Wilkie.

In November 2021, Explore Energy hosted an in-person launch event, which was delayed a year due to COVID-19. Hundreds of undergraduate and graduate students attended. Dozens of Stanford organizations participated, including student and alumni groups, as well as research and internship programs.

Understand Energy to go global

Understand Energy is a Stanford course. It is also a new program to help people address climate change and sustainability issues, engage with equity and human development challenges, participate in energy industry markets and technology innovations, and make informed energy decisions. Project manager Sharon Poore and the Understand Energy team are building a public web portal with free and easy access to information curated from the Understand Energy course, which has been taught for more than 30 years.

The course, taught by Jane Woodward, Kirsten Stasio and Diana Gragg, continues to be offered fall, spring and summer terms, serving more than 300 students annually. This summer 117 students from around the world – undergraduates and high school students – took Understand Energy. A record of 116 Stanford students took the course in fall 2021. Program manager Justine Dachille joined the team in August to assist with the steadily increasing student enrollment and planned expansion of the Understand Energy course offerings.

Staff expect to have a prototype for the public web portal built by spring 2022 and to launch the portal later in the year. Their goal is to broaden the reach of Understand Energy to millions of people through the portal and a new Understand Energy channel on YouTube.

A workshop for Stanford faculty and staff is also in the works, as is a Stanford Online course.
Startup course delivers on investment

Stanford Climate Ventures is a unique Stanford course: It focuses completely on energy and climate entrepreneurship. Students learn how to identify and assess the commercial potential of technologies to reduce or manage the damage of climate change, and then how to design, launch and build high-impact startups.

The course is supported by Tom and Johanna Baruch. In the five years ending August 2021, its 59 projects have resulted in:

- 30 startups
- $200.5 million in funding
- 232 employees in 16 states and eight countries.

Starting in 2020, the teachers dedicated the fall term to a more traditional seminar series: Big Ideas & Open Opportunities in Climate-Tech Entrepreneurship. Some 140 students registered for fall 2021 and 118 students received permission to audit the course. Teachers of the course attribute the significant increase in interest to the new wave in venture capital and startup creation in climate tech. When they started the course in 2016, venture capital activity in this space was tiny.

The traditional Stanford Climate Ventures course is offered in winter and spring terms. Teams of four to six students develop their projects as well as the skills that will enable them to become innovation leaders. Students and teams often take the course in both winter and spring. All courses were taught in 2020-21 by David Danielson, Joel Moxley and Jane Woodward.

Eight in cleantech make Forbes’ “30 Under 30”

Forbes’ 2021 “30 Under 30” included three Stanford students and five recent alumni developing energy- and sustainability-related technologies. In the past nine years “30 Under 30” has recognized 36 students and alumni in cleantech, mostly in energy.

The 2021 “Energy” group featured students Grayson Zulauf, David Mackanic and Nicolas “Nico” Pinkowski, and as well as alumni Kaitlyn Albertoli, Annie Baldwin, Vikhyat “Vik” Chaudhry and Jay Schwalbe. In the “30 Under 30 in Consumer Technology” category, alumnus Tevon Strand-Brown was recognized for his sustainable mobility service.

Of the six startups recognized, five had received Innovation Transfer grants from the TomKat Center early in their development, in addition to support from other Stanford programs.

“The entire Stanford energy ecosystem is the whole package – mentorship, technology experts, inspiration, funding, collaborations – that makes clean-energy entrepreneurship possible here,” said Zulauf, whose research and startup benefited from TomKat and Precourt Institute seed grants, the course Stanford Climate Ventures, and the Innovation Transfer Program.

Mackanic founded Anthro Energy, which is commercializing materials that he developed at Stanford for flexible, non-flammable lithium-ion batteries. Mackanic received financing and other support at Stanford from TomKat, StartX and Cardinal Ventures, as well as from Stanford affiliate H4Xlabs.

Pinkowski and Schwalbe co-founded Nitricity, which makes fertilizer from only air, water and renewable electricity. In addition to benefiting from the TomKat Center, Stanford Climate Ventures and StartX, the Nitricity team won the Stanford BASES 100K Challenge.

Some notable Stanford Climate Ventures projects that have become startups.
The Precourt Institute and its centers and programs supported 75 undergraduate and graduate students in summer internships in 2021.

Through the TomKat Center’s energyStartup internship program, 34 undergraduate and master’s degree students learned about entrepreneurship working at startups from Stanford in the energy/cleantech space. Founders of most of the startups are previous recipients of Innovation Transfer grants. The energyStartup program began in 2014 with four positions.

The Shultz Energy Fellowships program selected 17 graduate and undergraduate students during winter quarter 2021. After a spring term course, the Shultz fellows worked remotely on regulatory policy issues with host agencies in California, Colorado, Utah and Hawaii. Each fellow had an agency mentor and a Stanford faculty mentor. The program is a partnership of the Precourt Institute, Bill Lane Center for the American West, Haas Center for Public Service, and Stanford in Government.

The program’s goals are for Stanford students to learn about the regulatory environments in which they may work and to consider careers in public service. Two recent interns have continued to work with their agencies in full-time jobs after graduating.

The Summer Undergraduate Program on Energy Research internships match Stanford undergraduates with Stanford faculty in energy research. Twelve students were supported in 2021, either in spring or summer, based on the university’s residence plans. The program is supported by Michael and Chrissi Morgan, and Stanford’s Vice Provost for Undergraduate Education.

In one project this year, rising sophomores Cynthia Chen and Haley Stafford worked with June Flora and Prof. Ram Rajagopal’s lab to build an energy usage program for high school students to visualize and understand their energy use data. Both students continued their research during the 2021-22 academic year under Rajagopal’s National Science Foundation grant.

In conjunction with the Haas Center, the TomKat Center also provides stipends each summer to selected Stanford undergraduates to work on a sustainable energy research project with significant social impact. This summer, the five Energy Impact Fellows completed a study addressing the crisis of plastic waste.

Three summer interns from the Graduate School of Business developed briefs for potential partners in a developing Precourt initiative to help organizations meet their pledges to eliminate their greenhouse gas emissions. The TomKat Center supported two undergraduates to work over the summer on applied projects that are critical for the Stanford Solar Car team. The Sustainable Finance Initiative launched its Summer Fellowship Program in 2021, co-sponsoring two graduate students who had secured fellowships with organizations whose missions are aligned with SFI’s focus areas.

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75 summer 2021 internships

The TomKat Center Postdoctoral Fellowships awarded full support for two years to three new postdoctoral researchers in fall of 2021. The program attracts talented early-career researchers to Stanford. Arundhati Desmucha (UCLA) is working in Hemamala Karunadasa’s lab. Tania Ferreira (University of Louvain, Belgium) is working with Catherine Gorle, and Mickey Stone (MIT) is mentored by Matteo Cargnello.
Global Energy Forum returns

After being delayed for two years, the second Global Energy Forum at Stanford is set for May 3 and 4, 2022. The premier energy event at Stanford brings together industry leaders, energy experts, problem solvers and policy makers to address holistically the challenges of the global energy transition. The forum will be a big part of the new Stanford Energy Week, which will include the launch of the Precourt Institute’s initiative on hydrogen research, advisory council meetings for the Bits & Watts and StorageX initiatives, and a smaller meeting on early-stage startups and venture financing.

Global Energy Forum will be an in-person engagement. The event will include the Startup Showcase, which like the 2018 forum will feature ventures built on cleantech inventions developed as Stanford research. The Stanford ENERGY Showcase will provide interaction with the many energy research and education programs across campus.

Some of the forum’s talks and panels will be thematically organized in line with Stanford’s major energy initiatives, including new initiatives in development. The university will also update participants about the new school focused on climate and sustainability.

Since the postponement of Global Energy Forum in 2020, the online Global Energy Dialogues have kept the Global Energy Forum community engaged. Guests this year included Bill Gates, Amazon’s head of sustainability Kara Hurst, Bank of America vice chair Anne Finucane, ReNew Power chair and managing director Sumant Sinha, and Envision Group CEO Lei Zhang. About 1,000 people on average tuned in to the 12 dialogues held during the fiscal year to watch live and ask questions. More than 20,000 people have viewed the recordings on the Stanford ENERGY YouTube channel.

Engaging with others continued to be a challenge from September 2020 to August 2021, though the dawn of a hybrid new day could be seen. Precourt Institute faculty, students and staff took advantage of the ability to expand engagement online. As in-person meetings began to resume, the institute began to select the most effective option or mix of options among different means of interacting.
Disclosing climate-related financial risks

The State of California should translate specific risks associated with climate change into financial terms and use that information in deciding how to spend its $260 billion annual budget and manage more than $1 trillion in state pension fund investments. That’s according to a group of advisors to Gov. Gavin Newsom led by Alicia Seiger, managing director of the Precourt Institute’s Sustainable Finance Initiative.

The 20-person advisory group Seiger chaired included Dan Iancu, associate professor at Stanford’s GSB, and Thomas Heller, faculty director of the Sustainable Finance Initiative and emeritus professor at Stanford Law School. The group was appointed in April 2021 and released its report in September. Among its recommendations:

- California should require entities that do business with the state to disclose their climate risks and plans to transition to carbon neutrality, especially for large infrastructure and procurement expenditures.
- California’s three big pension funds for state employees should pressure companies in which they invest to make climate risk part of their regular financial reporting and to move toward decarbonization. These funds can use climate risk metrics to better evaluate investments under increasingly strict climate regulation and the costs of climate impacts, including heat, drought, fires and floods. Disclosure can also be used to help drive investment in companies whose products reduce climate change and its impacts.

Also, California’s three big pension funds for state employees should pressure companies in which they invest to make climate risk part of their regular financial reporting and to move toward decarbonization. These funds can use climate risk metrics to better evaluate investments under increasingly strict climate regulation and the costs of climate impacts, including heat, drought, fires and floods. Disclosure can also be used to help drive investment in companies whose products reduce climate change and its impacts.

Seiger and Iancu explained in a Stanford News interview the importance of climate risk assessment and reporting, the justifications for their recommendations and the road to implementation.

Murkowski:
Carbon price “worth putting on the table”

In October 2020, the Stanford Environmental & Energy Policy Analysis Center (SEEPAC) organized a live dialogue with U.S. senators Lisa Murkowski (R-AK) and Sheldon Whitehouse (D-RI) that addressed the question: “What are the prospects for bilateral action on climate change policy in the coming U.S. Congress?” The conversation, facilitated by SEEPAC researchers Lawrence Goulder and Charles Kolstad, has attracted more than 2,800 viewers.

The dialogue identified important areas of agreement between the two senators. Both spoke in favor of federal support for improved energy efficiency, for carbon capture and sequestration, and for technological innovation in energy supply. Importantly, both senators said they are willing to consider carbon pricing – a willingness seldom displayed by Republicans.

“I know that a price on carbon is one that makes Republicans more than a little bit nervous,” Murkowski said. “But I do think that can be and that should be one of the options that is on the table for discussion, in terms of how you can move policies forward.”

Whitehouse suggested that Democrats, if they won control of the Senate, would pass a major climate bill without Republicans if necessary through budget reconciliation.

Murkowski advised against that.

“If we’re going to really address the reality of climate change, it has to be enduring policy,” she said. “And I don’t think that you get there through use of partisan tools, like the removal of the filibuster and reconciliation.”

StorageX Initiative expands research and outreach

The StorageX Initiative supported more than a dozen Stanford faculty members with almost $1 million in research funding in fiscal year 2021, its second full year of operation. The initiative also facilitated about $11 million in new sponsored research starting fiscal year 2021. Co-directors Yi Cui and Will Chueh launched two new consortia this year: one on the circular economy of batteries, and the other on fast charging of batteries. Each consortium has three industry members.

In addition, the StorageX International Symposium Series continued to take advantage of virtual meetings to build a global community of energy storage scientists and business people. 2020-21 guests included J.B. Straubel, QuantumScape’s chief technology officer Timothy Holme, MIT faculty members Jennifer Rupp and Elsa Olivetti, as well as Stanford professors Steven Chu, Zhenan Bao, Thomas Jaramillo and Robert Laughlin, among others. The semi-monthly webinars drew 950 viewers on average. The 21 recordings on the Stanford ENERGY YouTube channel have been viewed more than 50,000 times.

C3E annual symposium

Stanford’s Simona Onori won the Clean Energy Education & Empowerment (C3E) initiative’s award for research at C3E’s annual symposium and awards conference, held virtually in December 2020. An assistant professor in the Department of Energy Resources Engineering, Onori researches transportation and grid storage systems. Her contributions to sustainable transportation include designing novel algorithms to improve fuel economy of hybrid vehicles, developing advanced battery management systems for electric vehicles and second-life utilization, and proposing innovative modeling tools to accelerate adoption of new emissions reduction technologies.

C3E inspires women to pursue careers and leadership roles in clean energy by recognizing achievements and providing professional networks for mentoring. The initiative is a collaboration of the U.S. Department of Energy, the Precourt Institute, MIT Energy Initiative and the Texas A&M Energy Institute.

Tough road: Decarbonizing heavy-duty transport

The Stanford Hydrogen Focus Group hosted a workshop in April 2021 to discuss the challenges of decarbonizing heavy-duty transportation. Participants included: executives from Airbus, Shell, Toyota, Alstom, Trafigura and AC Transit; Stanford and national laboratory researchers; and state, local and federal policy makers.

The group explored the challenges in trucks, buses, trains, ships and airplanes, as well as infrastructure challenges. In August, the group produced a report detailing the state of the transition to zero emissions in the heavy-duty transport sector. The primary options for zero emission vehicles include battery electric vehicles and hydrogen fuel cell electric vehicles. These technologies are still in the early stages of development and have yet to significantly penetrate the heavy-duty transport market.

As the report explains, most experts see batteries gaining market share for lighter vehicles with low daily use, while fuel cells are the likely solution for heavier vehicles with high daily use. Battery electric transport offers some of the same advantages in the heavy-duty sector as it does with passenger cars, but becomes challenged as power and energy density needs increase. Four-fold longer charging times become expensive for larger transport vehicles and vessels. An ensemble of applications around an industrial area such as a commercial port may be restrictive in terms of land-use required for longer duration electrical charging vs. refueling with hydrogen.

Still, the report concludes, the heavy-duty transport sector has broadly diverse needs that warrant strong consideration of both batteries and hydrogen for decarbonization.
$35 million in free legal services for startups

**Lawyers for a Sustainable Economy**, a joint effort of Stanford Law School and the Precourt Institute, continued to grow with sustained outreach efforts. It now has 18 major, private law firms involved. That’s up from 14 firms last year and double the original number of firms. The firms pledged more than $15 million in pro bono legal services for 2021.

A small team under the direction of Stanford Law School professor Deborah Sivas has secured legal help for many more applicants than in previous years. In the second half of fiscal 2020-21, the initiative matched 40 sustainability-focused startups and nonprofits with law firms for free legal help.

Many of the applicants are working on climate and energy issues, including:

- Creating a climate tech marketplace for local impact investing;
- Designing new efficient heat pumps that help decarbonize heating and cooling;
- Increasing energy efficiency in computing;
- Working to replace jet fuel with biogas-derived liquid natural gas;
- Converting inactive oil and gas wells into energy storage.

**Social media coverage**

**FY 2017 through FY 2021**

![Graph showing social media metrics](image_url)

**Cui captures E.O. Lawrence Award, Global Energy Prize and AAAS Fellow**


The award cited “exceptional contributions in nanomaterials design, synthesis and characterization for energy and the environment, particularly for transformational innovations in battery science and technology.”

The director of the Precourt Institute also won the 2021 Global Energy Prize for new energy applications, one of three Global Energy Prizes given annually. The international Global Energy Prize recognizes outstanding scientific research and technical developments in energy that promote greater efficiency and environmental security. Previous winners include Nobel Prize laureates Zhorez Alferov of Russia, Shuji Nakamura of the United States, and Akira Yoshino of Japan, who won the 2019 Nobel Prize in Chemistry for his contributions to the development of lithium-ion batteries.

In November 2020, Cui was one of six researchers from Stanford and SLAC National Accelerator Laboratory to be named fellows of the American Association for the Advancement of Science in recognition of their “scientifically or socially distinguished efforts to advance science or its applications.”
FISCAL YEAR 2022: THE LOOK AHEAD

The current fiscal year and beyond hold much promise for the Precourt Institute and Stanford making major contributions to sustainable, affordable, secure energy for all people. Precourt Institute’s leadership, advisors and senior fellows are actively helping to plan the university’s new school focused on climate and sustainability. The university leadership has prioritized research and education on urgent issues facing the planet. The institute’s major objectives are aligned with the university’s emerging plans.

Stanford Woods Institute for the Environment will also be an essential component of the new school. Woods and Precourt will launch a major research program on removing greenhouse gases from the atmosphere in fiscal year 2022. Faculty across campus and beyond will carry out the research needed to capture, utilize and store carbon emissions – both CO₂ and methane – on a large scale in a sustainable way. Faculty leadership and staff, working with potential sponsors, have defined the scope of the initiative’s research and are ready to go.

Also in fiscal year 2022, the Precourt Institute, Stanford Natural Gas Initiative and SUNCAT Center for Interface Science & Catalysis will launch a research initiative on hydrogen. Scores of Stanford researchers are doing significant work in the area of hydrogen. The initiative will support research across campus to holistically overcome the barriers to widespread use of hydrogen for deep decarbonization globally. It will work with industry, governments and thought leaders to translate research into scalable technologies, policies and business models.

Also in 2022, the Precourt Institute plans to launch a new research and education program to help the many companies, governments and other organizations that have pledged net-zero carbon emissions in the coming decades. These entities, including Stanford, have much to learn to deliver on this promise. Faculty, students and staff will work with the program’s external partners to develop cost-effective, scalable solutions to challenges such as electricity decarbonization, sustainable transportation, mapping and accounting of emissions throughout supply chains, circular economy science and engineering, and business models. The program will support sustainability-related education for partners’ employees, and convene meetings large and small to promote collaboration, shared knowledge and best practices.

As described earlier in this report, the Global Energy Forum will return in May 2022. The goal is to meet or exceed the high bar for excellence set at the first Global Energy Forum on campus in 2018.

At the same time, the Precourt Institute’s existing programs must and will continue to deliver results in energy research, education and engagement to address climate change and extend the benefits of sustainable, affordable and secure energy to all people.

Altogether, this is quite a tall order. The institute and the university are assembling the talent, knowledge, dedication and resources to deliver on these key objectives.
Bits & Watts Initiative | bitsandwatts.stanford.edu
Bits & Watts develops innovations for the 21st century electric grid that are needed to incorporate large amounts of clean power and a growing number of distributed energy resources, while simultaneously enabling grid reliability, resilience, security and affordability.

Energy Modeling Forum | emf.stanford.edu
Energy Modeling Forum improves the use of energy and environmental policy models for making important corporate and government decisions. EMF harnesses the collective capabilities of multiple models to improve the understanding of important energy and associated environmental problems. This helps explain the strengths and limitations of competing approaches to a given problem, providing guidance for future research efforts.

Explore Energy | energy.stanford.edu/explore-energy
Explore Energy is students’ one-stop resource for energy education at Stanford. The new program’s mission is to increase energy literacy, experiential learning, mentoring and networking at Stanford. Explore Energy supports Precourt Institute-related courses. Its staff oversees the institute’s two internship programs, the annual boot camp for new graduate students interested in energy, the Explore Energy student dormitory, and extension of the Understand Energy course to a public, online education portal.

Mexico Clean Economy 2050 | www.mce2050.com
Mexico Clean Economy 2050 is a neutral platform intended to inform and support low-carbon economic development in Mexico. Led by Stanford scholars and co-sponsored by industry and government partners, the program aims to advance technological, business, policy and social solutions for a carbon-neutral future.

Stanford Energy Corporate Affiliates | seca.stanford.edu
Stanford Energy Corporate Affiliates promotes interaction between companies and Stanford’s faculty and graduate students across the full range of energy-related topics. It is for corporate affiliates whose interests lie in multiple initiatives or outside existing initiative topics, for example energy market policy reforms. The Stanford Energy Corporate Affiliates program coordinates all of the industrial affiliate activities of the Precourt Institute.

Stanford Environmental & Energy Policy Analysis Center | seepac.stanford.edu
The Stanford Environmental & Energy Policy Analysis Center was established to develop practical and economically viable solutions to the pressing energy and environmental problems facing 21st Century societies. SEEPAC, a joint venture of the Stanford Institute for Economic Policy Research and the Precourt Institute, undertakes and disseminates research that can help decision makers shape environmental and energy policy.

Stanford Natural Gas Initiative | ngi.stanford.edu
The Natural Gas Initiative is an industrial affiliate program through which members support Stanford researchers in engineering, science, policy, geopolitical and business disciplines to advance the knowledge needed to use natural gas to its greatest social, economic and environmental benefit. NGI is a joint effort of Stanford’s School of Earth, Energy & Environmental Sciences and the Precourt Institute.

StorageX Initiative | storagex.stanford.edu
The StorageX Initiative accelerates the research, development, translation and adoption of energy storage solutions. From materials science and computer science to economics and energy resources engineering, the interdisciplinary initiative is addressing gaps between academic and industrial R&D.

Strategic Energy Alliance | energy.stanford.edu/strategic-energy-alliance
The Strategic Energy Alliance is a unique vehicle for large global companies to form research and educational relationships with Stanford that could provide strategic direction and input toward a low carbon energy future.

Sustainable Finance Initiative | sfi.stanford.edu
The Sustainable Finance Initiative works to scale-up and accelerate the flow of capital to decarbonize global systems by developing and promoting policies and financial mechanisms, educating leaders, and engaging with the global policy and finance community.

TomKat Center for Sustainable Energy | tomat.stanford.edu
The TomKat Center empowers students, researchers, and innovators to develop and externalize impactful solutions in energy and sustainability. The center funds graduate and postdoctoral fellows, summer internships and fellowships, as well as grant programs that inspire and catalyze the skills and creativity of the Stanford community. Its Innovation Transfer Program supports students and recent alumni in advancing technologies developed in their laboratories toward commercialization.
IN MEMORIAM: GEORGE P. SHULTZ

Former U.S. Secretary of State George P. Shultz, distinguished fellow at the Hoover Institution and chairman of the Precourt Institute for Energy Advisory Council, who served three American presidents and played a pivotal role in shaping economic and foreign policy in the late 20th century, died Feb. 6, 2021 at his home on the Stanford campus. He was 100 years old.

One of the most consequential policy makers of all time and remembered as one of the most influential secretaries of state in American history, Shultz was a key player, alongside President Ronald Reagan, in changing the direction of history by using the tools of diplomacy to bring the Cold War to an end. He knew the value of one’s word, that “trust was the coin of the realm,” and stuck unwaveringly to a set of principles. This, combined with a keen intelligence, enabled him not only to imagine things thought impossible but also to bring them to fruition and forever change the course of human events.

Shultz’s extraordinary career spanned government, academia and business. He is one of only two Americans to have held four different federal cabinet posts – State, Treasury, Labor, and Office of Management & Budget. He taught at three renowned universities, and for eight years was president of a major engineering and construction company.

Shultz first joined Stanford in 1968 and had periodic affiliations with the university throughout his public service career, finally returning to campus in 1989. Always dedicated to his students and higher education, Shultz tackled some of humanity’s most difficult issues – including nuclear disarmament, climate change and democratic governance – in the classroom, in book and article form, and at events he hosted. Those issues drove him to keep working at Stanford nearly every day until his passing.

In 1982, Reagan names Shultz secretary of state at a time of heightened global tensions with the Soviet Union. The full measure of his talent at negotiation came when Shultz implemented a foreign policy approach that eased those tensions and led to several landmark arms control treaties. Shultz also was secretary of labor, the first director of the Office of Management & Budget and secretary of the treasury, all under President Richard Nixon.

Shultz was deeply committed to addressing climate change.

"Over the past four decades, the United States has been on an energy roller coaster that has landed us, unnecessarily, in a place that is dangerous to our economy, our national security and our climate," Shultz said in a 2008 announcement for an initiative he launched at the Hoover Institution, the Shultz-Stephenson Task Force on Energy Policy.

Shultz co-authored The State Clean Energy Cookbook – a collaboration between the Hoover Institution and the Steyer-Taylor Center for Energy Policy & Finance – that provided states with guidance on energy efficiency and renewable energy initiatives. The Precourt Institute changed the name of its student summer internship program working with state agencies in honor of Shultz in 2020.

Shultz’s numerous honors include the Medal of Freedom (1989), the nation’s highest civilian honor, as well as many honorary degrees. He was a member of the American Academy of Arts & Sciences and the American Philosophical Society.

Shultz’s wife, Charlotte Mailliard Shultz, passed away on Dec. 3, 2021 at age 88. Secretary Shultz is survived by his five children: Margaret Tilsworth, Kathleen Jorgensen, Peter Shultz, Barbara White and Alexander Shultz, as well as 11 grandchildren and nine great-grandchildren.

(Adapted from the Stanford News obituary.)
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