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on Energy, Economy and Environment

HARVARD-CHINA PROJECT NEWSLETTER

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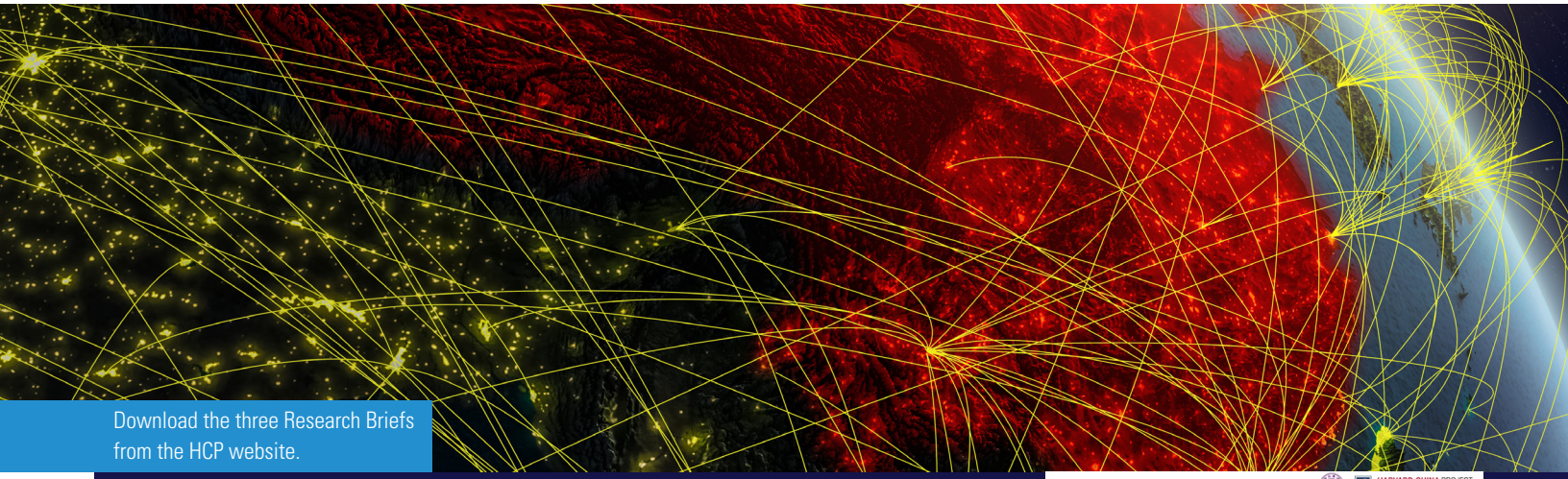


Download the three Research Briefs from the HCP website.

HCP RESEARCH BRIEFS

This fall, the Harvard-China Project created three Research Briefs for Non-Specialists, which detail new studies on solar power, hydrogen, and grid integration of renewable power. These publications, initially created as part of an Energy Foundation China grant, each contain a list of Key Takeaways to summarize the research, and more detailed figures and descriptions in the interior pages. The Key Takeaways are also translated into Chinese. The Research Briefs are available to read and download from our website under the "News" section.

Rising Cost Advantages of Solar Power in China and Coupled Electricity Storage for Greater Grid Compatibility (*PNAS*)

China has already made major commitments to transitioning its energy systems towards renewables, especially power generation from solar, wind and hydro sources. However, there are many unknowns about the future of solar energy in China, including its cost, technical feasibility and grid compatibility in the coming decades. Recent projections of the cost of future solar energy potential in China have relied on outdated and overestimated costs of solar panels and their installation, and storage technologies like lithium-ion batteries.

How much will solar power really cost in China in the coming decades, including the challenges its inherent variability poses to the grid?

Researchers from Harvard, Tsinghua University, Nankai University and Renmin University of China have found that solar energy could provide 43.2% of China's electricity demands in 2060 at less than two-and-a-half U.S. cents per kilowatt-hour. For comparison, coal power tariffs in China ranged 3.6 to 6.5 cents per kilowatt-hour in 2019. The research is published as the cover article of the *Proceedings of the National Academy of Sciences* (PNAS).

"The findings highlight a crucial energy transition point, not only for China but for other countries, at which combined solar power and storage systems become a cheaper alternative to coal-fired electricity and a more grid-compatible option," said **Michael B. McElroy**, the Gilbert Butler Professor of Environmental Studies at the Harvard John A. Paulson School of Engineering and Applied Sciences (SEAS) and co-author of the study.

"Today, subsidy-free solar power has become cheaper than coal power in most parts of China, and this cost-competitive advantage will soon expand to the whole country due to technology advances and cost declines," said **Xi Lu**, an alumni of

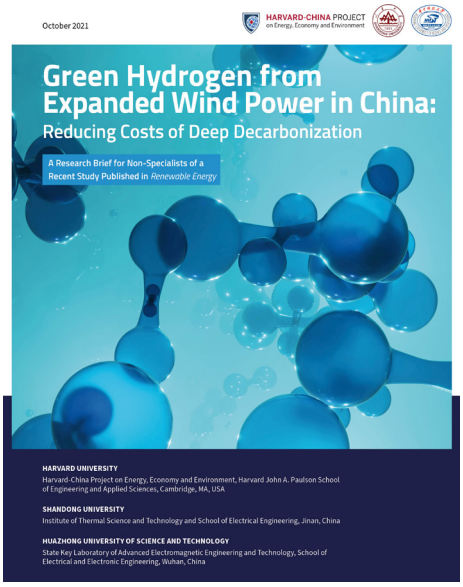
Read the Brief: https://bit.ly/3HI7gKs

SEAS and the Harvard-China Project who is Associate Professor, School of Environment, Tsinghua University and lead author of the paper. "Our results demonstrate that the economic competitiveness of solar power combined with investments in storage systems could provide extra benefits for grid dispatch, which will be especially important for operation of future electric systems in China."

By Leah Burrows | SEAS Communications

New Publication: Xi Lu, Shi Chen, Chris P. Nielsen, Chongyu Zhang, Jiacong Li, Xu He, Ye Wu, Shuxiao Wang, Feng Song, Chu Wei, Kebin He, Michael P. McElroy, and Jiming Hao. 2021. "Combined solar power and storage as cost-competitive and grid-compatible supply for China's future carbon-neutral electricity system." *Proceedings of the National Academy of Sciences*, 118, 42.

Green Hydrogen from Expanded Wind Power in China: Reducing Costs of Deep Decarbonization (*Renewable Energy*)



Read the Brief: https://bit.ly/3GrYoaB

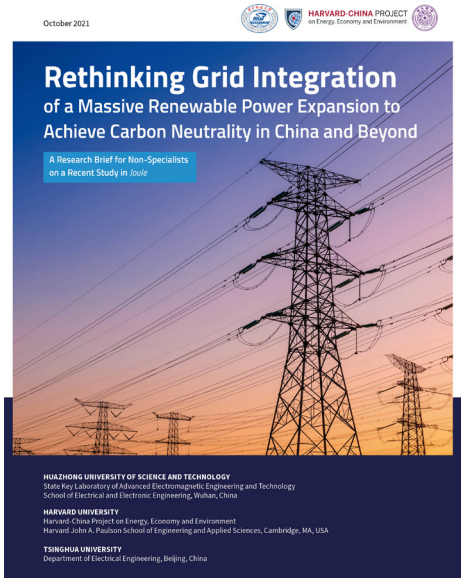
China is the world's largest producer of hydrogen – currently chiefly an industrial feedstock consumed by the chemical and refining industries – and overwhelmingly produces it from coal emitting CO_2, termed "black" hydrogen. China also leads the world in wind power generation, with 61% of its onshore wind capacity located in windy northern regions, where it must sometimes be wasted because the grid cannot accommodate its inherent variability. But renewable power can be used to produce hydrogen without CO_2 emissions, called "green" hydrogen, through electrolysis of water that can be timed to accommodate variations in renewable generation.

Now a team of researchers from Harvard University, Shandong University and Huazhong University of Science and Technology have explored the potential harnessing of China's wind energy to produce carbon-free green hydrogen at a cost lower than that of coal-derived black hydrogen. If green hydrogen can prove cost-competitive with black carbon for existing industrial uses, it may have even greater decarbonization potential as a zero-carbon energy source in key sectors that are otherwise difficult to decarbonize, including iron & steel production, cement making, and heavy-duty transportation.

The researchers chose Western Inner Mongolia, with its high wind power generation and large coal and black hydrogen production, as a representative region to estimate the technical and economic feasibility of producing green hydrogen using wind power. The results show that green hydrogen produced from wind power is competitive with black hydrogen, with large production levels possible at less than US$2/kg – a widely recognized threshold for cost-competitiveness. And by 2030, shifting black hydrogen to green hydrogen derived from Western Inner Mongolia's growing wind power for use as industrial feedstocks alone could reduce about 100 million tons of CO_2 emissions per year, equal to roughly half of the entire carbon footprint of the megacity of Beijing.

By Kellie Nault

New Publication: Haiyang Lin, Qiuwei Wu, Xinyu Chen, Xi Yang, Xinyang Guo, Jiajun Lv, Tianguang Lu, Shaojie Song, and Michael B. McElroy. 2021. "Economic and technological feasibility of using power-to-hydrogen technology under higher wind penetration in China." *Renewable Energy*, 173, 569-580.



Read the Brief: https://bit.ly/3uC1VRi

Rethinking Grid Integration of a Massive Renewable Power Expansion to Achieve Carbon Neutrality in China and Beyond (*Joule*)

There are many uncertainties about pathways to mid-century carbon neutrality in China and other major emitting nations, but one fundamental aspect is certain: they will require massive expansions of wind and solar power to displace coal- and gas-fired power. The problem is not the cost and feasibility of sufficient renewable generation, but rather the challenges it introduces into the grid because of its variability: the wind doesn't always blow and the sun doesn't always shine.

Now, in a new paper published in *Joule*, a team of researchers from Harvard University, Huazhong University of Science and Technology and Tsinghua University have developed a cross-sector, high-resolution model to find the best and most cost-effective way for China's power system to become carbon neutral by 2050. A comprehensive strategy moving beyond conventional planning assumptions to include large offshore wind generation, power storage, electric vehicles, green hydrogen production, and expanded transmission to balance power on a national basis can sharply reduce costs of integrating renewable power into the grid. In fact, the results show that realizing the carbon neutrality of China's power system by 2050 is not only feasible but need not necessarily cost more than reliance on coal- and gas-fired power, with no carbon constraints at all, to meet future electricity demands.

New Publication: Xinyu Chen, Yaxing Liu, Qin Wang, Jiajun Lv, Jinyu Wen, Xia Chen, Chongqing Kang, Shijie Cheng, and Michael B. McElroy, 2021, "Pathway toward carbon-neutral electrical systems in China by mid-century with negative CO2 abatement costs informed by high-resolution modeling." *Joule,* 5, 10, 2715-2741.

RESEARCH UPDATES

Hydrogen Produced from Offshore Wind in China Can Help Japan Reach it's GHG Emission Goals

Japan's Green Growth strategy signals a commitment to net-zero greenhouse gas emissions by 2050 – and hydrogen produced from renewable energy can play an important role in this shift. A team of researchers from Harvard University, Shandong University, China University of Petroleum Beijing and Huazhong University of Science and Technology have explored the possibility of producing hydrogen by electrolysis using power generated from offshore wind in China.

"This research helps build the case that it is not only possible for Japan to meet the formidable challenge of transitioning to net-zero emissions, it also could be cost-competitive," explains lead author **Shaojie Song**, Research Associate in the Harvard-China Project. "Our research shows that Chinese-produced hydrogen could be delivered at a volume and cost consistent with Japan's future projections."

The team analyzed the potential for a green hydrogen supply chain to Japan delivered from offshore wind produced in China on an hourly basis from every Chinese coastal province, considering several possible wind investment levels, electrolysis technologies and transport mechanisms. The generated hydrogen could be delivered to Japan either as liquid hydrogen, bound to a chemical carrier such as toluene, or as a component of ammonia.

The researchers determined that offshore wind power from China could provide potentially as much as 12 petawatt-hours of electricity annually. They modeled the cost implications of the offshore wind location; chemical conversion processes; and storage, transport, and delivery methods. The team found that Chinese sources could supply cost-competitive hydrogen to Japan for 2030 even if offshore wind deployment follows a high-cost scenario.

New Research: Shaojie Song, Haiyang Lin, Peter Sherman, Xi Yang, Chris P. Nielsen, Xinyu Chen, and Michael B. McElroy. 2021. "Production of hydrogen from offshore wind in China and cost-competitive supply to Japan." *Nature Communications*, 12, 2021, 6953.

Modeling Emissions Pathways for India's Climate Amid COVID-19 Recovery

As the global economic recovery from COVID-19 continues, decisions regarding emissions strategies can have important implications on regional climate change. A new paper in *Environmental Research Letters* explores the impact of such decisions in India, modeling the effects of COVID-19 emissions recovery pathways on India's summertime climate.

"Anthropogenic emissions can be linked to extreme weather events in India and beyond," explains **Peter Sherman**, a postdoc in the Harvard-China Project on Energy, Economy and Environment in the Harvard University John A. Paulson School of Engineering and Applied Sciences and recent Ph.D graduate in Harvard's Department of Earth and Planetary Sciences. "This study provides an important discussion on how India – a nation which is likely to be particularly susceptible to climate change over the coming decades – may be affected by emissions changes as the world transitions out of the COVID-19 pandemic."

The team of researchers—which include Harvard undergraduate Jonathan D'Souza as first author and two high school students from Cambridge Rindge and Latin School (mentored by Harvard University and University of Cambridge researchers) as contributing authors—modeled the impact of three different scenarios on India's climate: fossil-based recovery, a strong renewable-based recovery and a moderate scenario in between the two.

The team found that a fossil fuel-based recovery pathway leads to higher summertime aerosol concentrations in the long term, in contrast to greener scenarios. The greener scenarios may actually drive a positive feedback loop, where the solar PV capacity factor improves with reduced air pollution – incentivizing further investment in renewables which should further reduce aerosol emissions.

The researchers also found that extreme temperature and precipitation events in India are expected to increase in magnitude and frequency regardless of the emissions commitments going forward. However, the spatial patterns of these changes as well as the extent of the change are pathway dependent. They found that while decreasing fossil fuel emissions will reduce the greenhouse effect (and consequently extreme temperature events), concurrent emissions reductions in aerosols and their precursors may balance these effects at the regional level.

New Research: Jonathan D'Souza, Felix Prasanna, Luna-Nefeli Valayannopoulos-Akrivou, Peter Sherman, Elise Penn, Shaojie Song, Alexander Archibald, and Michael B. McElroy. 2021. "Projected changes in seasonal and extreme summertime temperature and precipitation in India in response to COVID-19 recovery emissions scenarios." *Environmental Research Letters,* 16, 11, 114025.

INTRODUCING HCP'S NEWEST POSTDOCS

Haiyang Lin, Ph.D. Shandong University

Haiyang Lin, HCP postdoc and recent Ph.D. graduate in Power Engineering and Engineering Thermophysics from Shandong University, grew up in city of Shouguang, Shandong Province, China. Shouguang is known as the hometown of vegetables, and from a young age Haiyang saw all kinds of fruits and vegetables grow from cultivation to maturation, which Haiyang says is the most ancient and natural energy process for humans to use solar energy. So it was only natural for him to combine his natural aptitude for mathematics and physics with his energy interests in his current role as a Harvard-China Project postdoctoral fellow.

Haiyang has worked on integrated energy system simulation and optimization for the past several years, where he studies the characteristics of energy supply and demand. "My work here aims to address the economic feasibility and decarbonization potential of renewable power, biomass energy and green hydrogen application by combining a techno-economic model for optimal design and operation of a low carbon energy system," explains Haiyang. He is studying the decarbonization strategies for China, Japan and India, in which hydrogen is considered to play a key role in facilitating the transition to a future deeply decarbonized energy system, and can help accommodate higher penetrations of renewables in the power system.

As Haiyang continues his work as an energy researcher, he appreciates the interdisciplinary nature of the Harvard-China Project. "Integrated energy system studies require inputs from multiple disciplines, such as electricity, economics, climate, transportation and so on," he explains. "In this group, I have access to these experts and can fill in the blanks of my study easily. It is remarkable that so many people with different expertise are working towards the same goal."

Peter Sherman, Ph.D. Harvard University

Peter Sherman, HCP postdoc and recent Ph.D. graduate from Harvard's Department of Earth & Planetary Sciences, says he looks back at his graduate years at Harvard with gratitude for his mentorship role of undergraduates and local high school students. "Giving younger people the opportunity to learn about (and occasionally struggle with!) research has helped me refine my pedagogical but also scientific perspectives in ways I did not envision when I started mentoring," Peter explains. "From these experiences, I have learned how to better synthesize and present research in ways that can more easily 'stick' with people learning about the science of climate change." Peter's enthusiasm for energy and climate change research translates to his new role as Harvard-China Project postdoctoral fellow, where he is working to help understand the scope of the climate crisis and offer solutions that could be implemented to mitigate these issues.

Peter's focus is on how regional climate change impacts people and how we can try to reduce some of the major consequences by decarbonizing our energy system – much of which builds upon his Ph.D. research. "We are particularly focused on means of decarbonizing the electricity sector as well as some of the harder-to-abate sectors, and have a few projects in mind that aim to follow up on the past research we have done on India's electricity sector and green hydrogen," says Peter. "I am also interested in projects focusing on the intersection of climate and energy, and am currently working on a smaller project looking at the impacts of climate change on future air conditioning demand (and the consequent impacts on the electricity grid because of it)."

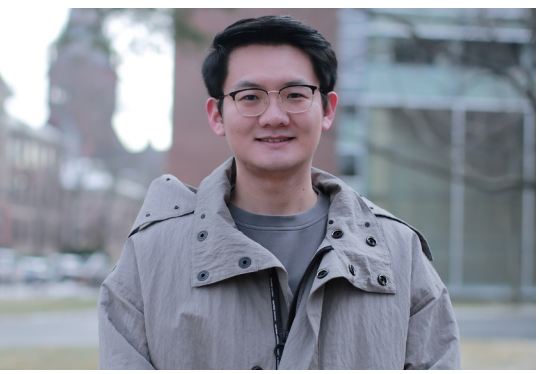
Peter looks forward to continuing his collaboration with Harvard-China Project colleagues, noting that "the group as a whole is fantastic because there are experts from all sorts of fields, from climate, to atmospheric chemistry to energy systems planning. This fosters an environment that is incredibly intellectually stimulating, where conversations in group meetings can quickly lead to major cross-disciplinary projects. We never run out of things to research!"

WELCOMING HCP'S VISITING FELLOWS

Zheng Wang

For **Zheng Wang**, a Ph.D. candidate from Peking University, an interest in energy was a fabric of his childhood. Growing up in Yan'an, Shaanxi Province, China, where "water can be burned (oil)" was recorded during the Eastern Han Dynasty (around 32 AD), the first oil well in China was built in 1905 in Zheng's elementary school. "Growing up, I had close contact with fuel and energy, which has given me a certain understanding of the role of energy in industrial development and socio-economic progress, and energy's role as one of the main sources of income for the local government," explains Zheng. "This made me curious about the real role of energy in the socio-economy."

Zheng sees the shifting role of energy in society firsthand, as his hometown transitions to renewable energy sources like wind and solar power. He plans to continue his renewable energy research while at Harvard. He first plans to calculate the capacity potential of Chinese onshore and offshore wind power under various scenarios (e.g. grid connection, diverse energy storage) at different times (2030, 2060). He will use this data to explore the efficiency and economic costs of wind power at different altitude levels, and compare Chinese wind power and photovoltaic costs. Zheng also plans to combine climate change models and land surface model simulations to consider the calculation of capacity requirements for long-term energy storage for wind-PV-storage systems in different regions.



Chen Xiang

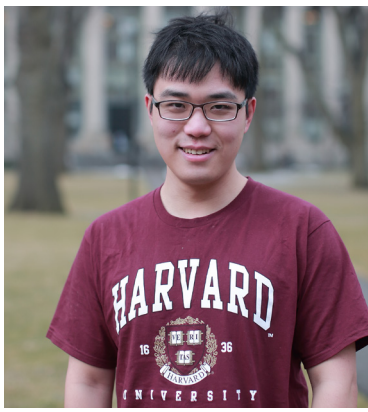
For Hong Kong University Ph.D. candidate **Chen Xiang**, it was an environmental volunteerism trip to Antigua, Guatemala where she worked on water filtration that sparked her career in environmental governance. "Despite the fact that I tried to approach as many local people as possible to share information on mitigating water contamination, I realized the limitations of my own effort – without an improvement of institutional arrangement and state capacity (a top-down approach), it would be very difficult to improve the quality of drinking water in the least developed states," explains Chen. "This was my 'Aha!' moment: applying what I have learned from global governance and politics, and adopting an approach of environmental governance to solve real-life issues and address environmental justice."

Later, while studying the process and mechanism of how the EU helped China build its own emissions trading system, Chen further cemented her career interests. "My research seeks to understand the role of carbon markets as a means to overcome weak incentives of carbon emissions mitigation in China," says Chen. She is also working on a second project that surveys public attitudes toward climate change to explore how China's global climate leadership aspirations are disconnected across different local scales.

Xinyang Guo

While in junior high school, distributed solar PV street lamps and

small-scale wind turbines appeared in **Xinyang Guo**'s hometown of Xingyang, Hubei Province. "At that time, I felt that this way of power generation was very novel," he said. "Later, I learned that nature has endless renewable energy, which could be easily converted into electricity." A few years later he met his current advisor, Professor Xinyu Chen – also a former Harvard-China Project researcher. Together, they explored offshore wind as a means towards decarbonization. "I realized that offshore wind power was indispensable for the ambitious target of carbon neutralization, and the construction of trans-continental interconnections in Northeast Asia," he says. It was these experiences that led him to pursue his current coursework as a Ph.D. candidate at the Huazhong University of Science and Technology, and continue to develop his research on carbon neutrality of energy systems while a Harvard-China Project Visiting Fellow. At Harvard, he is drawing on input from other researchers, including Professor Michael B. McElroy. "What has impressed me most is the communication with Professor Mike. His thinking on research points and story lines is very original and in-depth."



HCP IN THE NEWS

OCT 13 South China Morning Post

'Key to China's power future': cost of solar to match coal power by 2023, scientists say
By Holly Chik | Photo: Xinhua

SOLAR POWER, when paired with adequate storage capacity, could meet more than 40 per cent of the country's electricity demands by 2060, say researchers.

Decarbonizing the energy system is a priority for China to deal with air pollution at home and global climate change, according to the Chinese-US paper.

Full article at https://bit.ly/3tRLwb1

NOV 03 ClimateWire

Here to save the day: 'Supergrids' in China and the U.S.
By John Fialka | Photo: Adobe

A MASSIVE GRID that can route electricity over long distances may not seem like a useful response to climate change. But experts say so-called supergrids are critical to the mass adaption of renewable energy sources — and China and the United States both have made strides recently to help turn this vision into reality.

"I would be very surprised if the Chinese government would not be extremely interested in this," said Michael McElroy, a Harvard University professor.

Full article at https://bit.ly/3GAtq06

Nov/ Dec Harvard Magazine

China's Excess Wind Energy
By Jacob Sweet | Photo: Taylor Callery

THERE'S A PROBLEM with sustainable energy, and it will only grow with time. The problem is intermittency—what to do when the wind dies or the sun goes down.

Storing extra energy in batteries can alleviate some intermittency problems, but Professor Michael McElroy believes that using renewable energy produced by utilities in working power grids to make hydrogen—a portable, storable fuel source that produces only water as a byproduct when burned in a fuel cell—is a better solution.

Full article at https://bit.ly/3rE6jw3

Prem Shankar Jha, HCP Visiting Fellow, Earns Lifetime Achievement Award by Mumbai Press

Prem Shankar Jha, an Indian journalist, writer, economist and Harvard-China Project Visiting Fellow, was recognized for his distinguished writing career and significant contributions to the journalism field. Jha was presented a RedInk Award for Lifetime Achievement, given by the Mumbai Press Club in India. This annual collection of awards celebrates excellence in journalistic achievements, as determined by an accomplished jury. The award was presented to Jha by the Chief Justice of India NV Ramana.

"It is profoundly gratifying for any writer to be appreciated by his readers, but it is even more so when the recognition comes from one's peers," says Jha. "One thing that I always followed in my journalism career was that I never overruled my consciousness to protect my career. In this age of digitization, everyone can be tracked all the time; we journalists should be careful and fight for the truth."

To learn more about the Harvard-China Project community of collaborators, please visit our website: https://chinaproject.harvard.edu/contributors

MEET HCP UNDERGRADUATE RESEARCHERS

Jack Walker '24

An eighth-grade science project sparked a commitment to study clean energy for **Jack Walker** '24. Tasked to present on a specific alternative energy source, Jack creatively parodied rapper Drake's "Views From the Six" album, which Jack renamed "Fuels From the Six." Says Jack of the project, "Parodying the songs actually helped me understand nuclear fission to a much higher degree; I discovered new facts and perspectives on nuclear energy."

Jack maintained his focus on alternative energy throughout high school, culminating with a research stint into microbial electrolysis cells for hydrogen fuel production at the Frederick National Lab. Now, as a Chemistry and Environmental Science & Public Policy dual concentrator, Jack is working as an HCP Research Assistant on decarbonizing the global shipping industry, a project that builds upon his HCP Summer Research Assistantship. Jack's summer research analyzed the potential for modern sailing, green hydrogen, green ammonia, and electric battery propulsion. His team discovered that a hybrid propulsion mechanism might be the best option for the majority of the maritime sector—using an electric battery for in-port maneuvering and green ammonia/hydrogen combustion for open-sea travel.

Following graduation, Jack will commission as a 2nd Lieutenant in the US Air Force.

Candice Chen '22

Spending her freshman year summer in Santiago, Chile, **Candice Chen** '22 studied smog's impact on respiratory health.

This drove Candice to enroll in atmospheric chemistry courses, ultimately enrolling as a dual Environmental Science and Engineering and Earth and Planetary Sciences concentrator. "I found my love for climate and environmental science because I loved exploring questions fundamental to Earth's habitability and human wellbeing under anthropogenic climate change," says Candice.

Now, as an HCP Research Assistant, Candice is studying the shift to natural gas from coal in the Beijing region. "This work will inform estimates of CH_4 leakage, informing cost-benefit analyses on the coal-to-gas conversion and mitigation strategies," explains Candice.

RECENT PUBLICATIONS: NOVEMBER TO FEBRUARY

Shaojie Song, Haiyang Lin, Peter Sherman, Xi Yang, Chris P. Nielsen, Xinyu Chen, and Michael B. McElroy. 2021. **"Production of hydrogen from offshore wind in China and cost-competitive supply to Japan."** *Nature Communications*, 12, 2021, 6953.

Xinyu Chen, Yaxing Liu, Qin Wang, Jiajun Lv, Jinyu Wen, Xia Chen, Chongqing Kang, Shijie Cheng, and Michael McElroy. 2021. **"Pathway toward carbon-neutral electrical systems in China by mid-century with negative CO2 abatement costs informed by high-resolution modeling."** *Joule*, 5, 10 (20 October), 2715-2741.

Jonathan D'Souza, Felix Prasanna, Luna-Nefeli Valayannopoulos-Akrivou, Peter Sherman, Elise Penn, Shaojie Song, Alexander Archibald, and Michael B McElroy. 2021. **"Projected changes in seasonal and extreme summertime temperature and precipitation in India in response to COVID-19 recovery emissions scenarios."** *Environmental Research Letters,* 16, 11, 114025.

Yingying Lyu and Ann Forsyth. 2021. **"Planning, aging, and loneliness: Reviewing evidence about built environment effects."** *Journal of Planning Literature*, August.

Yu Zhao, Mengxiao Xi, Qiang Zhang, Zhaoxin Dong, Mingrui Ma, Kaiyue Zhou, Wen Xu, Jia Xing, Bo Zheng, Zhang Wen, Xuejun Liu, Chris P. Nielsen, Yang Liu, Yuepeng Pan, and Lei Zhang. 2022. **"Decline in bulk deposition of air pollutants in China lags behind reductions in emissions."** *Nature Geoscience*.

Faan Chen, Chris P. Nielsen, Jiaorong Wu, and Xiaohong Chen. 2022. **"Examining socio-spatial differentiation under housing reform and its implications for mobility in urban China."** *Habitat International*, 119, January, 102498.

Jianglong Li and Mun Ho. 2022. **"Indirect cost of renewable energy: Insights from dispatching."** *Energy Economics*, 105, January, 105778.

Jianglong Li, Mun S. Ho, Chunping Xie, and Nicholas Stern. 2022. **"China's flexibility challenge in achieving carbon neutrality by 2060."** *Renewable and Sustainable Energy Reviews*, 158, April, 112112.

Haiyang Lin, Caiyun Bian, Yu Wang, Hailong Li, Qie Sun, and Fredrik Wallen. 2022. **"Optimal planning of intra-city public charging stations."** *Energy*, 238, Part C, 121948.

Shaodan Huang, Shaojie Song, Chris P. Nielsen, Yuqiang Zhang, Jianyin Xiong, Louise B. Weschler, Shaodong Xie, and Jing Li. 2022. **"Residential building materials: An important source of ambient formaldehyde in mainland China."** *Environment International*, 158, January, 106909.

Rong Tang, Jing Zhao, Yifan Liu, Xin Huang, Yanxu Zhang, Derong Zhou, Aijun Ding, Chris Nielsen, and Haikun Wang. 2022. **"Air quality and health co-benefits of China's carbon dioxide emissions peaking before 2030."** *Nature Communications*, 13, 1008.

2022年冬/春

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on Energy, Economy and Environment

HARVARD-CHINA PROJECT NEWSLETTER

哈佛大学中国项目新闻通讯

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封面图片：夕阳下的上海

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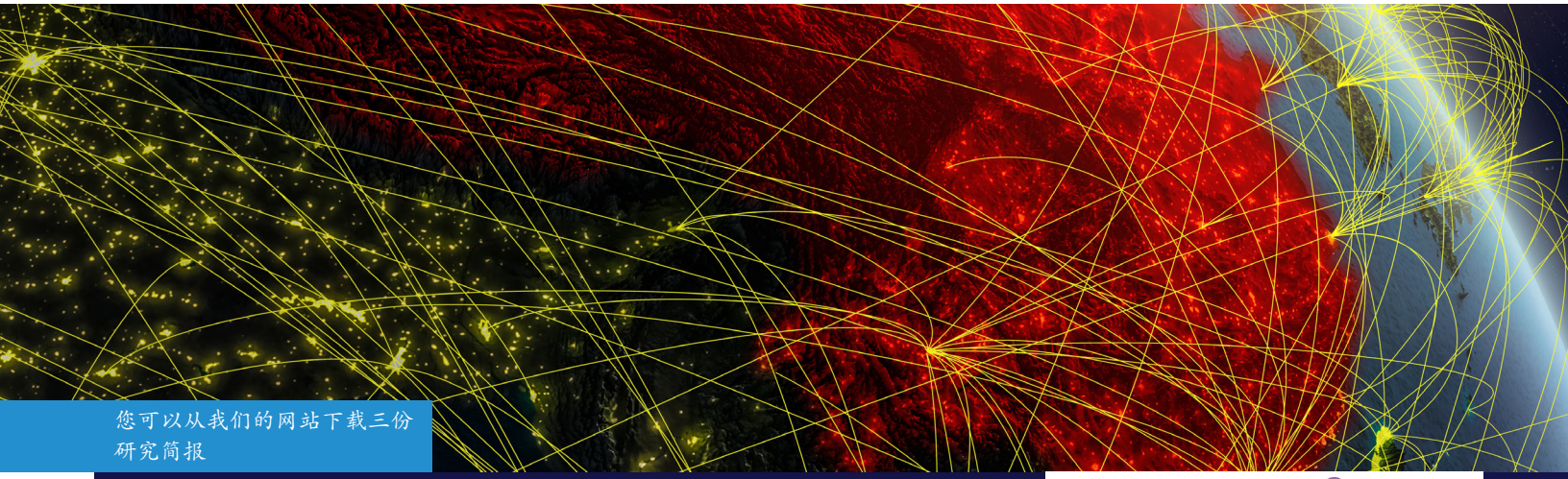

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哈佛中国项目研究简报

今年秋天，哈佛-中国项目为非专家读者编写了三份研究简报，详细介绍了关于太阳能、氢能和可再生能源并网的新研究。这些出版物最初是作为能源基金会中国资助的一部分而创建的，每个出版物都包含一份总结研究的关键要点清单，以及更详细的数字和内页描述。关键信息简报也有中文版本。研究简报可从我们网站的“新闻”部分阅读和下载。

中国太阳能成本优势不断上升，耦合储能可提高电网兼容性（美国科学院院刊）

中国已经做出重大承诺，将其能源系统向可再生能源转型，特别是太阳能、风能和水力发电。然而，中国太阳能的未来还有很多未知数，包括未来几十年的成本、技术可行性和电网兼容性。最近对中国未来太阳能潜力成本的预测依赖于过时和高估的太阳能电池板及其安装成本，以及锂离子电池等存储技术。

未来几十年，太阳能在中国的真正成本将是多少，包括其固有的出力可变性对电网构成的挑战？

哈佛大学、清华大学、南开大学和中国人民大学的研究人员发现，到2060年，太阳能可以供给中国43.2%的电力需求，每千瓦时不到2.5美分。相比之下，2019年中国的煤电电价为每千瓦时3.6至6.5美分。该研究作为《美国国家科学院院刊》(PNAS)的封面文章发表。

哈佛大学约翰·A·保尔森工程与应用科学学院(SEAS)环境研究吉尔伯特·巴特勒教授和该研究的合著者Michael B. McElroy总结：“研究结果突出了一个关键的能源转型点，不仅对中国，而且对其他国家而言，太阳能和储能系统相结合，将成为燃煤发电更具成本竞争力的替代品，且具有良好的电网兼容性。”

哈佛中国项目校友，清华大学环境学院副教授，论文第一作者SEAS校友鲁玺说：“如今，在中国大部分地区没有补贴的情况下太阳能已经比煤电更具成本优势，而且由于技术进步和成本下降，这种成本竞争优势将很快扩展到全国。我们的研究结果表明，太阳能的经济竞争力与对储能系统的投资相结合，可以为电网调度带来额外的好处，这对于中国未来电力系统的运营尤为重要。”

简介导读：https://bit.ly/3HI7gKs

由 *Leah Burrows* | *SEAS*报导

新出版物： Xi Lu, Shi Chen, Chris P. Nielsen, Chongyu Zhang, Jiacong Li, Xu He, Ye Wu, Shuxiao Wang, Feng Song, Chu Wei, Kebin He, Michael P. McElroy, and Jiming Hao. 2021. “Combined solar power and storage as cost-competitive and grid-compatible supply for China’s future carbon-neutral electricity system.” *Proceedings of the National Academy of Sciences*, 118, 42.

中国风力发电的绿色氢能：降低深度脱碳的成本 （可再生能源期刊）

简介导读：**https://bit.ly/3GrYoaB**

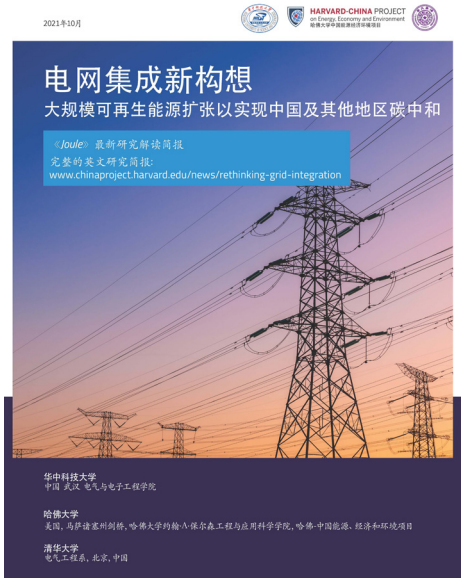
由*Kellie Nault*整理报导

中国是世界上最大的氢气生产国——目前主要是化学和炼油工业消耗的工业原料——并且绝大多数是通过排放二氧化碳的煤炭生产氢气，称为“黑色”氢气。中国在风力发电方面也处于世界领先地位，其陆上风电装机容量的 61% 位于多风的北方地区，由于电网无法适应其固有的可变性，有时不得不将其弃置。但可再生能源可用于生产氢气而不会排放二氧化碳，称为“绿色”氢气，通过电解水可适应可再生能源发电的变化。

现在，来自哈佛大学、山东大学和华中科技大学的一组研究人员探索了利用中国风能以低于煤制黑氢的成本生产无碳绿色氢的潜力。如果绿色氢在现有工业用途中能够证明与黑色氢相比具有成本竞争力，那么它作为零碳能源在钢铁生产、水泥制造、重型运输和其他难以脱碳的关键领域可能具有更大的脱碳潜力。

研究人员选择了风力发电量大、煤炭和黑氢产量大的内蒙古西部作为代表地区，估算了利用风力发电生产绿色氢的技术和经济可行性。结果表明，风力发电生产的绿色氢与黑色氢具有竞争力，其成本可能低于 2 美元/千克——这是成本竞争力的公认门槛。 到 2030 年，利用内蒙古西部不断增长的风力发电将黑氢替换为绿氢，仅用作工业原料，每年可减少约 1 亿吨二氧化碳排放，相当于特大城市北京的全部碳足迹的约一半 。

新出版物： Haiyang Lin, Qiuwei Wu, Xinyu Chen, Xi Yang, Xinyang Guo, Jiajun Lv, Tianguang Lu, Shaojie Song, and Michael B. McElroy. 2021. “Economic and technological feasibility of using power-to-hydrogen technology under higher wind penetration in China.” *Renewable Energy*, 173, 569-580.



简介导读：**https://bit.ly/3uC1VRi**

重新思考大规模可再生能源部署的电网整合，以实现中国及其他地区的碳中和（焦耳期刊）

中国和其他主要排放国实现本世纪中期碳中和的途径存在许多不确定性，但有一个基本方面是确定的：它们将需要大规模扩大风能和太阳能以取代燃煤和燃气发电。 问题不在于足够的可再生能源发电的成本和可行性，而是由于其可变性而给电网集成带来的挑战：风并不总是在吹，太阳并不总是照耀。

在《焦耳》杂志上发表的一篇新论文中，来自哈佛大学、华中科技大学和清华大学的研究人员团队开发了一种跨部门、高分辨率的模型，旨在为中国找到最佳、最具成本效益的电力系统 2050 碳中和路径。超越传统规划假设的综合战略，包括大型海上风力发电、电力存储、电动汽车、绿色氢气生产和扩大输电以在全国范围内平衡电力，可以大幅降低可再生能源并入电网的系统集成成本。 事实上，研究结果表明，到 2050 年实现中国电力系统的碳中和不仅是可行的，而且在完全没有碳约束的情况下，满足未来电力需求的成本并不一定高于依赖煤电和燃气发电。

新出版物： Xinyu Chen, Yaxing Liu, Qin Wang, Jiajun Lv, Jinyu Wen, Xia Chen, Chongqing Kang, Shijie Cheng, and Michael B. McElroy, 2021, "Pathway toward carbon-neutral electrical systems in China by mid-century with negative CO2 abatement costs informed by high-resolution modeling." *Joule,* 5, 10, 2715-2741.

研究动态

中国海上风电制氢可帮助日本实现温室气体排放目标

日本的绿色增长战略标志着到2050年实现温室气体净零排放的承诺——可再生能源生产的氢气可以在这一转变中发挥重要作用。来自哈佛大学、山东大学和华中科技大学的一组研究人员探索了利用中国海上风电发电电解制氢的可能性。

“这项研究有助于证明日本不仅有可能应对向净零排放过渡的艰巨挑战而且还可能具有成本竞争力，”主要作者，哈佛中国博士后研究员宋少杰解释说。“我们的研究表明，中国生产的氢气可以以符合日本未来预测的需求和成本交付。”

该团队考虑了几种可能的风能投资水平、电解技术和运输机制，分析了中国每个沿海省份每小时由海上风电向日本输送绿色氢供应链的潜力。产生的氢气可以作为液态氢，与甲苯等化学载体结合，也可以作为氨输送到日本。

研究人员分析得出来自中国的海上风电每年可提供多达12拍瓦时的电力。他们模拟了海上风电位置的成本影响，化学转化过程，以及储存、运输和交付方法。该团队发现，即使海上风电部署遵循高成本方案，中国资源也可以在2030年向日本供应具有成本竞争力的氢气。

最新研究：Shaojie Song, Haiyang Lin, Peter Sherman, Xi Yang, Chris P. Nielsen, Xinyu Chen, and Michael B. McElroy. 2021. “Production of hydrogen from offshore wind in China and cost-competitive supply to Japan.” *Nature Communications*, 12, 2021, 6953.

在 COVID-19 复苏期间模拟印度气候的排放路径

随着全球经济从COVID-19继续复苏，有关排放策略的决策可能对区域气候变化产生重要影响。环境研究快报中的一篇新论文探讨了此类决定在印度的影响，模拟了COVID-19排放恢复途径对印度夏季气候的影响。

“人为排放可能与印度及其他地区的极端天气事件有关，”哈佛大学约翰·A·保尔森工程与应用科学学院哈佛-中国能源经济环境项目的博士后彼得·谢尔曼解释说。“这项研究就印度这个在未来几十年可能特别容易受到气候变化影响的国家进行了重要讨论，随着世界摆脱COVID-19大流行，排放变化可能会对其产生影响。”

研究人员团队——包括作为第一作者的哈佛大学本科生Jonathan D'Souza和来自剑桥林奇和拉丁学院的两名高中生（由哈佛大学和剑桥大学的研究人员指导）作为特约作者——模拟了三种不同情景对印度的气候：基于化石的复苏、基于可再生能源的强劲复苏以及介于两者之间的温和情景。研究小组发现，与更环保的情况相比，从长远来看，基于化石燃料的回收途径会导致夏季气溶胶浓度更高。更环保的情景实际上可能会推动一个正反馈循环，其中太阳能光伏发电容量系数会随着空气污染的减少而提高——激励对可再生能源的进一步投资，这将进一步减少气溶胶排放。

研究人员还发现，无论未来的排放承诺如何，预计印度的极端温度和降水事件的幅度和频率都会增加。然而，这些变化的空间模式以及变化的程度取决于路径。他们发现，虽然减少化石燃料排放将减少温室效应（以及随之而来的极端温度事件），但同时减少气溶胶及其前体的排放可能会在区域层面平衡这些影响。

最新研究：Jonathan D'Souza, Felix Prasanna, Luna-Nefeli Valayannopoulos-Akrivou, Peter Sherman, Elise Penn, Shaojie Song, Alexander Archibald, and Michael B. McElroy. 2021. “Projected changes in seasonal and extreme summertime temperature and precipitation in India in response to COVID-19 recovery emissions scenarios.” *Environmental Research Letters*, 16, 11, 114025.

介绍哈佛中国项目的新进博士后

蔺海洋，山东大学博士

蔺海洋，哈佛中国项目博士后，最近获得博士学位。他毕业于山东大学动力工程与工程热物理专业，成长于山东省寿光市。寿光素有蔬菜之乡的美誉，海洋从小就见证了各种果蔬从种植到成熟的过程，海洋称这是人类利用太阳能最古老、最自然的能源过程。因此，对于他来说，他将在数学和物理方面的天赋与他目前博士后研究的能源领域兴趣结合起来是很自然的。

过去几年，海洋一直致力于综合能源系统模拟和优化，研究能源供需特征。“我在这里的工作旨在通过结合技术经济模型来优化低碳能源系统的设计和运营，从而解决可再生能源、生物质能源和绿色氢应用的经济可行性和脱碳潜力，”海洋解释道。他正在研究中国、日本和印度的脱碳战略，其中氢被认为在促进向未来深度脱碳能源系统过渡方面发挥关键作用，并有助于提高可再生能源在电力系统中的渗透率。

随着海洋继续他作为能源研究员的工作，他非常感谢哈佛-中国项目的跨学科性质。“综合能源系统研究需要来自多个学科的投入，例如电力、经济学、气候、交通等，”他解释道。“在这个小组中，我可以接触到这些专家，可以轻松地填补我学习的空白。这么多具有不同专业知识的人正朝着同一个目标努力，这是非常了不起的。”

Peter Sherman, 哈佛大学博士

Peter Sherman, 哈佛中国项目博士后，他最近获得了博士学位。他毕业于哈佛大学地球与行星科学系。他说，回顾他在哈佛的研究生时光，他感恩对本科生和当地高中生的指导。“让年轻人有机会了解（偶尔会遇到困难！）研究帮助我以我开始指导时没有想到的方式完善了我的教学和科学观点，”彼得解释道。“从这些经验中，我学会了如何更好地综合和呈现研究，从而更容易‘坚持’人们学习气候变化科学。”彼得对能源和气候变化研究的热情转化为他作为哈佛中国项目博士后研究员的新角色，他正在努力帮助了解气候危机的范围并提供可以实施以缓解这些问题的解决方案。

彼得的重点是区域气候变化如何影响人们，以及我们如何通过使我们的能源系统脱碳来减少一些主要后果——其中大部分是建立在他的博士学位基础上的研究。“我们特别关注电力部门以及一些难以减排的部门的脱碳方法，并考虑了一些项目，旨在跟进我们过去对印度电力部门和绿色能源所做的研究，”彼得说。“我还对关注气候和能源交叉的项目感兴趣，目前正在开展一个较小的项目，研究气候变化对未来空调需求的影响（以及由此对电网造成的影响）。”

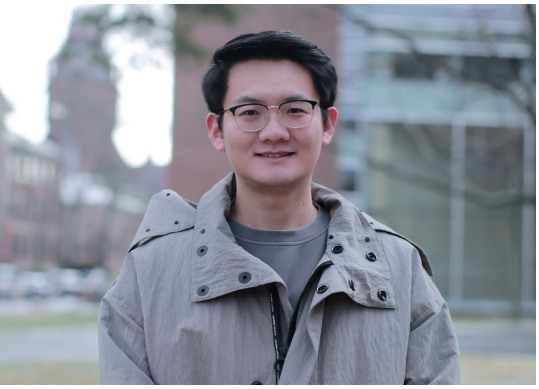
彼得期待继续与哈佛中国项目的同事合作，并指出“整个团队非常棒，因为有来自各个领域的专家，从气候到大气化学再到能源系统规划。这营造了一个令人难以置信的脑力激发环境，小组会议中的对话可以迅速开展重大的跨学科项目。我们永远都有值得研究的东西！”

欢迎哈佛中国项目的访问学生

王铮

王峥，博士。 来自北京大学，对能源的兴趣是他童年的一部分。 他成长于中国陕西延安，东汉时期（公元32年左右）有“水能烧（油）”的记载，中国第一口油井于1905年在郑氏国小修筑。“在成长过程中，我与燃料和能源有着密切的接触，这让我对能源在工业发展和社会经济进步中的作用，以及能源作为当地政府主要收入来源之一的作用有了一定的认识，”铮解释道。“这让我对能源在社会经济中的真正作用感到好奇。”

随着家乡向风能和太阳能等可再生能源转型，铮亲眼目睹了能源在社会中的角色转变。 他计划在哈佛继续他的可再生能源研究。 他首先计划计算中国陆上和海上风电在不同时间（2030年、2060年）不同场景（如并网、多样化储能）下的容量潜力。 他将利用这些数据探索不同海拔高度风电的效率和经济成本，并比较中国风电和光伏的成本。 铮还计划将气候变化模型和陆面模型模拟结合起来，考虑计算不同地区风-光-储系统长期储能的容量需求。



向晨

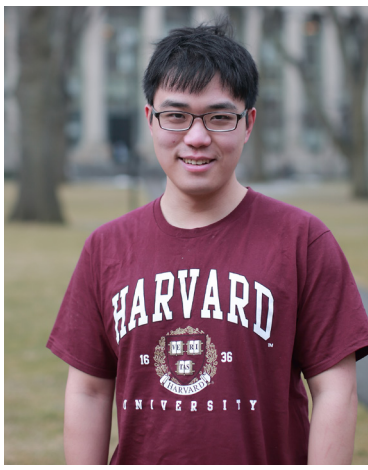
对于香港大学博士研究生向晨来说，她有过一次前往危地马拉安提瓜的环境志愿服务之旅，在那里她从事水过滤工作，从而开启了她在环境治理方面的职业生涯。“尽管我试图与尽可能多的当地人分享减轻水污染的信息，但我意识到自己努力的局限性——在没有改善制度安排和国家能力（自上而下的方法）的情况下，改善最不发达国家的饮用水质量将非常困难，”晨解释说。“这是我的‘啊哈！’时刻：应用我从全球治理和政治中学到的东西，并采用环境治理的方法来解决现实生活中的问题和解决环境正义问题。”

后来，在研究欧盟帮助中国建立自己的排放权交易体系的过程和机制的过程中，晨进一步巩固了自己的职业兴趣。“我的研究旨在了解碳市场作为克服中国减缓碳排放激励机制薄弱的一种手段的作用，”晨说。 她还在开展第二个项目，该项目调查公众对气候变化的态度，以探索中国的全球气候领导愿望如何在不同地方尺度上开展。

郭昕扬

博士生郭昕扬，来自华中科技大学。初中时，分布式太阳能光伏

路灯和小型风力发电机出现在郭昕扬的家乡湖北襄阳。“当时，我觉得这种发电方式很新颖，”他说。“后来，我了解到大自然具有无穷的能量，可以很容易地转化为电能。”几年后，他遇到了博士生导师陈新宇教授，他也曾是哈佛中国项目的研究员。他们开展了海上风电作为中国深度脱碳途径的研究。“我意识到海上风电对实现碳中这一雄心勃勃的目标以及在东北亚建立跨大陆互联互通是必不可少的，”他说。正是这些经历使他继续攻读博士学位，并在哈佛中国项目访问期间继续发展他对能源系统碳中和的研究。在哈佛，他正在吸取其他研究人员的意见，包括迈克尔麦克尔罗伊教授。“最让我印象深刻的是与Mike教授的交流。他对研究点和故事线的思考非常新颖和深入。”



哈佛中国项目在新闻媒体

10 月 13 日 南华早报

“中国电力未来的关键”：科学家称，到 2023 年太阳能成本将与煤电相匹敌

由 *Holly Chik* 报导 | 图片：新华社

研究人员表示，太阳能与充足的存储容量相结合，到 2060 年可以满足该国 40% 以上的电力需求。

中美联合报告称，能源系统脱碳是中国应对国内空气污染和全球气候变化的首要任务。

全文在 *https://bit.ly/3tRLwb1*

11 月 03 日 气候线报

拯救世界：中国和美国的“超级电网”

来自 *John Fialka* | 照片：*Adobe*

可以长距离输送电力的大型电网似乎不是对气候变化的有用响应。但专家表示，所谓的超级电网对于大规模适应可再生能源至关重要——中国和美国最近都在帮助将这一愿景变为现实方面取得了长足的进步。

“如果中国政府不对此非常感兴趣，那会让我们感到非常惊讶，”哈佛大学教授迈克尔麦克尔罗伊说。

全文在 *https://bit.ly/3GAtq06*

十一月 十二月 哈佛杂志

中国风能过剩

由 *Jacob Sweet* | 照片：*Taylor Callery*

可持续能源存在问题，它只会随着时间的推移而增长。问题是间歇性——当风停或太阳下山时该怎么办。

在电池中存储额外的能量可以缓解一些间歇性问题，但迈克尔麦克尔罗伊教授认为，使用电网中公用事业生产的可再生能源来制造氢气——一种便携式、可储存的燃料来源，在燃料电池中燃烧时只会产生水作为产品——是一个更好的解决方案。

全文在 *https://bit.ly/3rE6jw3*

哈佛中国项目客座研究员 Prem Shankar Jha，他获得孟买出版社颁发的终身成就奖

印度记者、作家、经济学家和哈佛中国项目访问学者 Prem Shankar Jha 因其杰出的写作生涯和对新闻领域的重大贡献而获得认可。Jha 获得了印度孟买新闻俱乐部颁发的 RedInk 终身成就奖。这一年度奖项旨在表彰杰出的新闻成就，这些成就由出色的评审团决定。该奖项由印度首席大法官 NV Ramana 颁发给 Jha。

“任何一位作家在得到读者的赞赏时，都会非常欣慰，但当得到同行的认可时，更是如此，”Jha 说。“我在新闻事业中一直遵循的一件事是，我从未推翻自己的意识来保护自己的职业生涯。在这个数字化的时代，每个人都可以无时无刻被追踪；我们记者应该小心，为真相而战。”

要了解有关哈佛中国项目合作者社区的更多信息，请访问我们的网站： https://chinaproject.harvard.edu/contributors

认识 哈佛中国项目本科生研究员

Jack Walker '24

一个八年级的科学研究项目激发了Jack Walker '24 致力于研究清洁能源的承诺。研究任务是展示一种特定的替代能源，Jack创造性地模仿了说唱歌手德雷克的"六人组的观点"专辑，杰克将这张专辑改名为"六人组的燃料"。该项目的杰克说："模仿这些歌曲实际上帮助我对核裂变的理解程度更高；我发现了关于核能的新事实和新观点。"

杰克在整个高中期间一直关注替代能源，最终在弗雷德里克国家实验室研究了用于生产氢燃料的微生物电解电池。现在，作为一名化学和环境科学与公共政策双专业人士，Jack 正在担任 哈佛中国项目研究助理，负责全球航运业的脱碳，该项目建立在他的哈佛中国项目夏季研究之上。杰克的夏季研究分析了现代航行、绿色氢、绿色氨和电池推进的潜力。他所在的团队发现，混合动力推进机制可能是大多数海事部门的最佳选择——使用电池进行港口机动，使用绿色氨/氢燃烧进行公海旅行。

毕业后，杰克将在美国空军担任第二中尉。

Candice Chen '22

在智利圣地亚哥度过了她的大一暑假，Candice Chen '22 研究了烟雾对呼吸系统健康的影响。 这促使 Candice 报名参加大气化学课程，最终报名参加了环境科学与工程和地球与行星科学双学位课程。"我发现自己对气候和环境科学的热爱是因为我喜欢探索人为气候变化下地球可居住性和人类福祉的基本问题，"Candice说。

现在，作为 哈佛中国项目研究助理，Candice 正在研究北京地区从煤炭向天然气的转变。"这项工作将为 甲烷泄漏的估计提供信息，为煤制气转化和缓解策略的成本效益分析提供信息，"Candice 解释说。

最近的出版物：11 月到 2 月刊

Shaojie Song, Haiyang Lin, Peter Sherman, Xi Yang, Chris P. Nielsen, Xinyu Chen, and Michael B. McElroy. 2021. **"Production of hydrogen from offshore wind in China and cost-competitive supply to Japan."** *Nature Communications*, 12, 2021, 6953.

Xinyu Chen, Yaxing Liu, Qin Wang, Jiajun Lv, Jinyu Wen, Xia Chen, Chongqing Kang, Shijie Cheng, and Michael McElroy. 2021. **"Pathway toward carbon-neutral electrical systems in China by mid-century with negative CO2 abatement costs informed by high-resolution modeling."** *Joule*, 5, 10 (20 October), 2715-2741.

Jonathan D'Souza, Felix Prasanna, Luna-Nefeli Valayannopoulos-Akrivou, Peter Sherman, Elise Penn, Shaojie Song, Alexander Archibald, and Michael B McElroy. 2021. **"Projected changes in seasonal and extreme summertime temperature and precipitation in India in response to COVID-19 recovery emissions scenarios."** *Environmental Research Letters,* 16, 11, 114025.

Yingying Lyu and Ann Forsyth. 2021. **"Planning, aging, and loneliness: Reviewing evidence about built environment effects."** *Journal of Planning Literature*, August.

Yu Zhao, Mengxiao Xi, Qiang Zhang, Zhaoxin Dong, Mingrui Ma, Kaiyue Zhou, Wen Xu, Jia Xing, Bo Zheng, Zhang Wen, Xuejun Liu, Chris P. Nielsen, Yang Liu, Yuepeng Pan, and Lei Zhang. 2022. **"Decline in bulk deposition of air pollutants in China lags behind reductions in emissions."** *Nature Geoscience*.

Faan Chen, Chris P. Nielsen, Jiaorong Wu, and Xiaohong Chen. 2022. **"Examining socio-spatial differentiation under housing reform and its implications for mobility in urban China."** *Habitat International*, 119, January, 102498.

Jianglong Li and Mun Ho. 2022. **"Indirect cost of renewable energy: Insights from dispatching."** *Energy Economics*, 105, January, 105778.

Jianglong Li, Mun S. Ho, Chunping Xie, and Nicholas Stern. 2022. **"China's flexibility challenge in achieving carbon neutrality by 2060."** *Renewable and Sustainable Energy Reviews*, 158, April, 112112.

Haiyang Lin, Caiyun Bian, Yu Wang, Hailong Li, Qie Sun, and Fredrik Wallen. 2022. **"Optimal planning of intra-city public charging stations."** *Energy*, 238, Part C, 121948.

Shaodan Huang, Shaojie Song, Chris P. Nielsen, Yuqiang Zhang, Jianyin Xiong, Louise B. Weschler, Shaodong Xie, and Jing Li. 2022. **"Residential building materials: An important source of ambient formaldehyde in mainland China."** *Environment International*, 158, January, 106909.

Rong Tang, Jing Zhao, Yifan Liu, Xin Huang, Yanxu Zhang, Derong Zhou, Aijun Ding, Chris Nielsen, and Haikun Wang. 2022. **"Air quality and health co-benefits of China's carbon dioxide emissions peaking before 2030."** *Nature Communications*, 13, 1008.