HARVARD-CHINA PROJECT
on Energy, Economy and Environment

HARVARD-CHINA PROJECT NEWSLETTER

INSIDE THIS ISSUE

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Cover Image: "Jade Dragon Snow Mountain" by Jiayin Lu, SEAS Ph.D. G2, a Harvard-China Project photo contest winner

The Harvard-China Project is based at the Harvard John A. Paulson School of Engineering and Applied Sciences and receives major support from the Harvard Global Institute on the theme of "China 2030/2050: Energy and Environmental Challenges for the Future."

CCICED MEETING '19

In early June, Professor Michael McElroy, chair of the Harvard-China Project, attended the annual general meeting of the China Council for International Cooperation on Environment and Development (CCICED) in Hangzhou with Project Executive Director Chris Nielsen. Co-chaired by Li Ganjie, China's Minister of Ecology and Environment, Xie Zhenhua, its Special Representative for Climate Change, and international counterparts from western governments and UN Agencies, CCICED is the highest international advisory body providing policy recommendations on environment and development to Vice Premier Han Zheng and China's State Council.

Among topics discussed at the annual meeting were the need to raise national goals and accelerate timelines (known formally as "Nationally Determined Contributions") under the Paris Agreement of the

UN Framework Convention on Climate Change, the need to make investments under the Belt and Road Initiative compatible with global deep decarbonization objectives, and China's hosting of the next Conference of the Parties to the UN Convention on Biological Diversity in 2020. Participation in CCICED provides the Harvard-China Project with an opportunity to introduce its research findings directly into discussions informing Chinese policy-making and to emphasize the role of independent research in understanding and addressing China's environmental and climate risks. It also strengthens Harvard-China Project relationships with leading decision makers on environment and development from across China and around the world.

Image by CCICED

James Hammitt by Claudio Cambon, HUCE // City image by Adobe Stock Photo

RESEARCH HIGHLIGHT

Professor James Hammitt's Research on Valuing Environmental Health Risk

Every society faces a challenge of deciding how much pollution control, and avoidance of associated health risks, is the right amount. The answer is certainly not 100% control—at least over policy-relevant timeframes, acknowledging limits of current technologies—because the marginal costs of abatement rise as pollution levels decline and become exorbitant as they approach zero. At some point it becomes wiser for society to shift limited public resources into other policies that offer comparable health or other benefits at lower costs.

One standard tool to help guide such decisions is benefit-cost analysis, in which all of the positive effects of pollution control (e.g., health benefits) and negative ones (e.g., control costs) are placed in common (monetary) units and compared. To complete such an analysis, the money value of reducing mortality risk—generally expressed in the value per statistical life, or VSL—is a crucial input.

James Hammitt, Professor of Economics and Decision Sciences at the Harvard T.H. Chan School of Public Health and Director of the Harvard Center for Risk Analysis, has been leading studies of environmental health risks and their value in Chinese society as part of the Harvard-China Project for more than 15 years.

Hammitt's latest research on VSL in China, co-authored by past or current Project affiliates Fangli Geng, Xiaoqi Guo, and Chris Nielsen, was published earlier this year in the *Journal of Risk and Uncertainty*. It takes advantage of rigorously sampled, interdisciplinary household surveys conducted by the Harvard-China Project with collaborators at Peking University in the city of Chengdu in both 2005 and 2016.

VSL is expected to increase with rising per capita income, but at what rate? The new Hammitt et al. study is close to unique in the international literature in estimating VSL in the same population, using the same methods, at two dates between which the local economy grew swiftly. It found rates of growth with respect to income substantially higher than most earlier studies; in economics lingo, it estimated an income elasticity for VSL

approaching 3.

In fact, the reasons for the rapid VSL increase are not resolved by the study, and could include other social changes in addition to a rise in income. In any case it suggests that Chinese policy-makers considering new investments or rules to reduce pollution should recognize that the value of health and safety in the eyes of citizens is likely to continue to increase rapidly. Any new policy interventions should prioritize public health more than if this trend were otherwise.

"At some point it becomes wiser for society to shift limited public resources into other policies that offer comparable health or other benefits at lower costs."

A second major finding concerns methodology. A problem with such survey-based "stated preference" studies is that respondents have limited understanding of small probability changes and can have a hard time determining their value. By eliciting values from each respondent for two different risk reductions, the study poses a test for internal consistency and identifies respondents whose answers indicate a clearer understanding of the premise. Limiting analysis to this sizable sub-sample results in a doubled VSL estimate, which implies that other VSL estimates based on full survey samples (as in most literature) might be biased downward by 50%.

The study, freely downloadable at the Harvard-China Project website, is: Hammitt, James K., Fangli Geng, Xiaoqi Guo, and Chris P. Nielsen. 2019. "Valuing mortality risk in China: Comparing stated-preference estimates from 2005 and 2016." Journal of Risk & Uncertainty 58 (2-3): 167–186.

FALL EVENTS RECAP

The Harvard-China Project hosted a number of Research Seminars and co-sponsored events this fall semester.

In September, **Yingying Lu**, a Harvard Graduate School of Design (GSD) doctoral candidate and incoming researcher of the Harvard-China Project, kicked off the fall semester events with her Ph.D. defense at GSD. Her talk, "Walking Culture in China," explored how walking contributes to the urban environment by reducing transportation energy consumption and emissions.

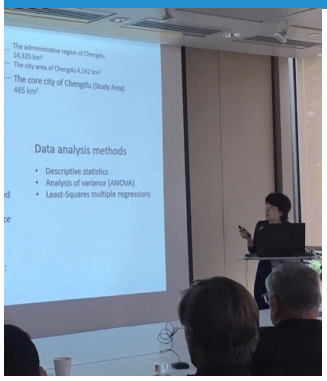
In October, **Siqi Zheng**, the Samuel Tak Lee Associate Professor of Real Estate Development and Entrepreneurship in the MIT Department of Urban Studies and Planning, delivered a talk on "Social Costs of Air Pollution in China." She contemplated the broader social costs of air pollution in Chinese cities by examining the negative effects of air pollution on social activities in cities, the social interactions embodied in such activities, and urbanites' subjective well-being.

Fengkui Duan, Associate Professor, School of Environment, Tsinghua University, China, presented on "Characteristics and Mixing State of Haze Pollution in China," which explored the chemical composition of PM2.5 during severe haze episodes in wintertime Beijing, which continue despite a decrease in annual average ambient $PM_{2.5}$ since 2013.

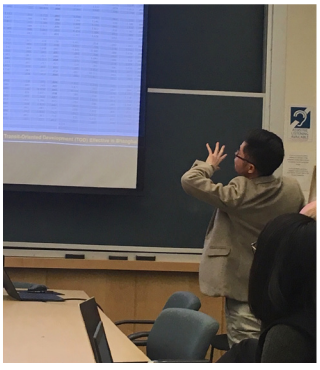
In November, **Faan Chen**, Postdoctoral Fellow in the Harvard-China Project, presented "Driving and the Built Environment: Is Transit-Oriented Development Effective in Shanghai?," which tested whether travel behavior is affected more by transit-oriented development or residential self-selection.

Cecilia Han Springer, Postdoctoral Research Fellow in the Harvard Kennedy School (HKS) concluded the fall semester with a December talk co-sponsored by the HKS Environment and Natural Resources Program on "Opportunities and Challenges in China's Carbon Market: From Model to Reality." She explored whether China's carbon market can be effective based on both modeling analyses and fieldwork on the operational challenges of the policies.

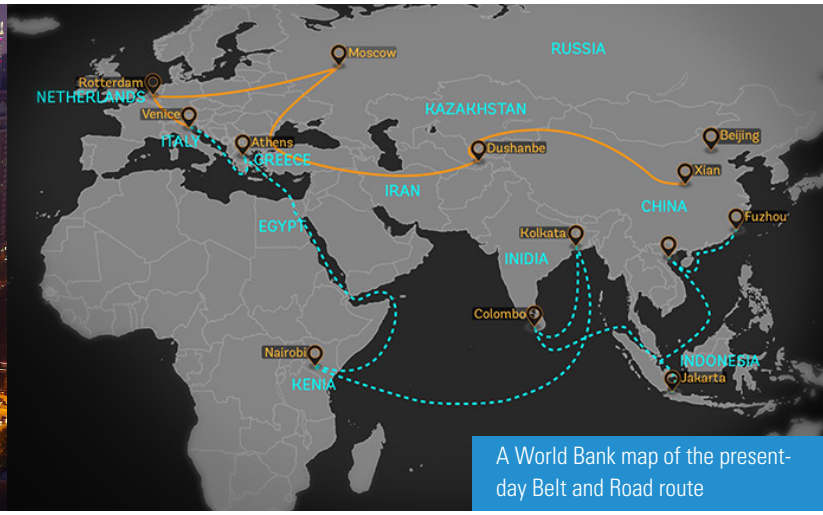
The Harvard-China Project also co-sponsored a September workshop organized by the Harvard Center for Risk Analysis to honor Prof. John S. Evans of the Harvard T.H. Chan School of Public Health. The two-day workshop, **"Risk Assessment, Economic Evaluation, and Decisions Workshop,"** explored the intersection of risk assessment and economics and featured papers from leading experts, including **seven Harvard-China Project affiliates or alumni** including Prof. Evans himself.






Xi'an, Shaanxi Province, marks the Eastern end of the Belt and Road



A World Bank map of the present-day Belt and Road route

RESEARCH HIGHLIGHT

Solar Energy Could Turn the Belt and Road Initiative Green

Researchers quantify the region's renewable energy potential

The region covered by the Belt and Road Initiative (BRI) has significant potential to be powered by solar energy, according to a recent study in the journal *Joule*. Less than 4 percent of the maximum solar potential of the region could meet the BRI's electricity demand for 2030. The research suggests a possible solution to reduce BRI countries' need for fossil fuels as they develop. This is the first time the renewable energy potential of the region is quantified.

The Chinese government launched the BRI in 2013, aiming to promote regional development and connectivity. "Belt" represents the Silk Road Economic Belt that echoes the ancient Silk Road, which linked Asia to Europe. "Road" refers to the 21st Century Maritime Silk Road that connects China to South East Asia, South Asia, and North Africa. So far, more than 120 countries in Asia, Europe, Africa, North America, South America, and Oceania are involved.

Constructing hard infrastructure, such as railways, buildings, and power plants, is a main focus of the initiative. However, most of the projects use large amounts of energy, resulting in high emissions. In addition, most countries involved in the BRI are developing countries. A proportion of their population doesn't have access to electricity. As the region develops under the initiative, the need for power is projected to increase.

"If we continue to rely on fossil fuels for energy, it can add significantly more CO_2 to the atmosphere, not just this year, but for the next few decades," says co-author Xi Lu at Tsinghua University. "This is not sustainable. If we want to achieve the emission reduction goal set by the Paris Agreement, we need renewable energy."

"The solar potential and cooperation opportunities revealed in this analysis is a chance for the BRI countries to leapfrog from their carbon-intensive trajectories to low-carbon futures"

Many BRI countries, especially those in West and South Asia, have high sun exposure, so Lu and his colleagues decided to assess the region's solar resource. The team selected 66 BRI countries that are connected geographically and built an integrative spatial model to calculate their solar power potential with high-resolution data.

The team first identified areas suitable for building solar farms. These areas would receive suffcient solar radiation and have lower land value otherwise--places like forests and agriculture land are excluded. Then they computed the spacing and packing density of solar panels, which absorb sunlight and generate energy, that would maximize power yield for each area. Finally, they calculated the areas' energy outputs in each hour after considering limiting factors like shading and temperature, which affects the performance of solar panels.

"Our model provides a comprehensive analysis of the region's solar energy potential by taking into account many influencing factors," Lu says. "We also calculated the solar energy outputs on an hourly basis, which is more accurate than previous estimates that use monthly data."

The team found that these countries can generate as much as 448.9 petawatt hour of energy, which is about 41 times the demand for electricity in these countries in 2016. Their 2030 electricity need could be satisfied by converting only 3.7 percent of the region's solar energy. To achieve this, it would require an investment of

$11.2 trillion and a land area of 88,426 square kilometers.

"If you make that commitment, the energy is free."

"The money is very large," says co-author Michael McElroy, the Gilbert Butler Professor of Environmental Studies at the Harvard John A. Paulson School of Engineering and Applied Sciences. "But if you make that commitment, the energy is free. Plus, the cost of building solar farms is coming down very dramatically because of the technological advances. We project it to become similar to fossil fuels within a decade."

The analysis also reveals a mismatch between the energy potential and the electricity demand. Countries with 70.7% of the potential consume only 30.1% of regional electricity. Therefore, cross-border power transmission grids can be utilized to maximize the benefits from solar energy through exporting surpluses of solar electricity to meet shortages in supplies of electricity elsewhere. To put such a project in action, international cooperation is essential.

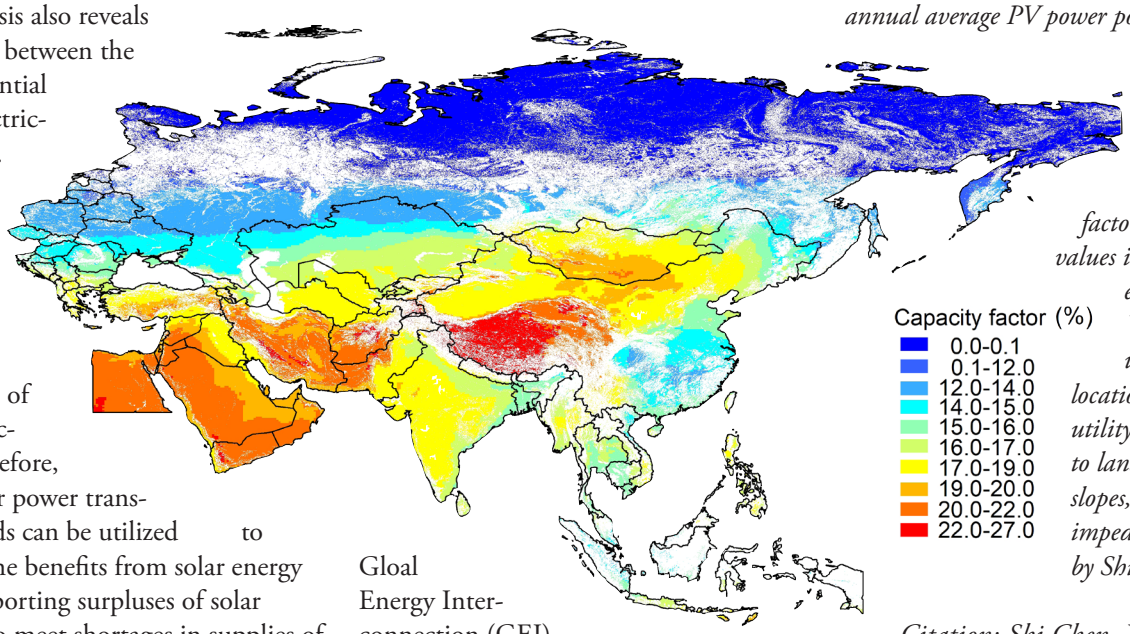
"It would be challenging, because different countries have different priorities when it comes to development," Lu says. "But the BRI is an opportunity as it sets up a framework for collaborations between countries, associations, and industries to happen. There are also funds and banks committed to promoting green development of the BRI, which provides financial support."

Because BRI countries span multiple time zones and various climate conditions, such cross-border grids would also help reduce the impact when sunlight isn't available in certain areas.

"This advantage coincides with the 'Facilities Connectivity' concept, which is one of the five cooperation priorities of the BRI," says the first author Shi Chen at Tsinghua University. "In the context of Gloal Energy Interconnection (GEI), solar power generation is bound to usher in a new development opportunity in the wave of trans-national and even trans-regional power interconnection."

"The solar potential and cooperation opportunities revealed in this analysis is a chance for the BRI countries to leapfrog from their carbon-intensive trajectories to low-carbon futures," says co-author Jiming Hao at Tsinghua University. "The opportunity to decouple future economic growth from increasing carbon emissions does exist."

"Our hope here is that this paper can influence the greening of BRI, so we can try to do the initiative in a better way," says McElroy. "And I'm optimistic about that."



Caption for Figure:

Distribution of Solar Capacity Factors across the BRI Region. Capacity factor reflects the annual average PV power potential given limits of technologies, strength of solar radiation, and other factors, with higher values indicating greater potentials. White areas are unsuitable locations for utility-scale PV due to land use, terrain slopes, and other impediments. Figure by Shi Chen.

Citation: Shi Chen, Xi Lu, Yufei Miao, Yu Deng, Chris P. Nielsen, Noah Elbot, Yuanchen Wang, Kathryn G. Logan, Michael B. McElroy, and Jiming Hao. 2019. "The potential of photovoltaics to power the Belt and Road Initiative." Joule, 3, Pp. 1-18.

By Yvaine Ye, Cell Press

INAUGURAL PHOTO CONTEST

This fall the Harvard-China Project launched an inaugural Photo Contest, which drew nearly 60 submissions for prizes in three separate categories: Natural Landscape of China; Energy and Environment in China; Urban Landscape and Cities of China. Submissions were received from University members across the Harvard John A. Paulson School of Engineering and Applied Sciences; Harvard College; Harvard Medical School; Harvard Graduate School of Design; Harvard T.H. Chan School of Public Health; and the Harvard Kennedy School. The cover image; photo at left (by Philip Milana, Harvard College 2021, Economics/EAS); and other images can be found on our website.

NEW PUBLICATIONS

Hammitt, James K., Fangli Geng, Xiaoqi Guo, and Chris P. Nielsen. 2019. **"Valuing mortality risk in China: Comparing stated-preference estimates from 2005 and 2016."** *Journal of Risk & Uncertainty* 58 (2-3): 167–186.

Gao, Meng, Peter Sherman, Shaojie Song, Yueyue Yu, Zhiwei Wu, and Michael B. McElroy. 2019. **"Seasonal prediction of Indian wintertime aerosol pollution using the Ocean Memory Effect."** *Science Advances* 5 (7): eaav4157.

Chen, Shi, Xi Lu, Yufei Miao, Yu Deng, Chris P. Nielsen, Noah Elbot, Yuanchen Wang, Kathryn G. Logan, Michael B. McElroy, and Jiming Hao. 2019. **"The potential of photovoltaics to power the Belt and Road Initiative."** *Joule* 3: 1-18. *Cover article of August edition of Joule.*

Cao, Jing, Mun S. Ho, Dale W. Jorgenson, and Chris P. Nielsen. 2019. **"China's emissions trading system and an ETS-carbon tax hybrid."** *Energy Economics* 81: 741-753.

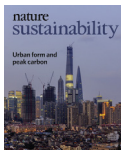
Sherman, Peter, Meng Gao, Shaojie Song, Patrick Ohiomoba, Alex Archibald, and Michael B. McElroy. 2019. **"The influence of dynamics and emissions changes on China's wintertime haze."** *Journal of Applied Meteorology and Climatology.*

Cao, Jing, Mun S Ho, and Wenhao Hu. 2019. **"Energy consumption of urban households in China."** *China Economic Review* 58.

Srinivasan, Sumeeta, Chenghe Guan, and Chris P. Nielsen. 2019. **"Built environment, income and travel behavior: Change in the city of Chengdu 2005-2016."** I*nternational Journal of Sustainable Transportation.*

Cao, Jing, Mun Sing Ho, Yating Li, Richard G. Newell, and William A. Pizer. 2019. **"Chinese residential electricity consumption estimation and forecast using micro-data."** *Resource and Energy Economics* 56: 6-27.

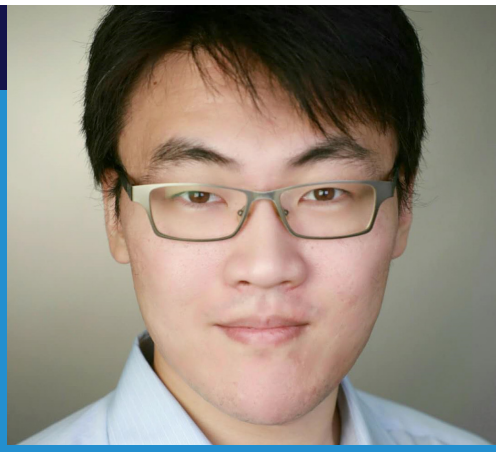
Guan, Chenghe. 2019. **"Spatial distribution of high-rise buildings and its relationship to public transit development in Shanghai."** *Transport Policy* 81: 371-380.



Wang, Haikun, Xi Lu, Yu Deng, Yaoguang Sun, Chris P. Nielsen, Yifan Liu, Ge Zhu, Maoliang Bu, Jun Bi, and Michael B. McElroy. 2019. **"China's CO2 peak before 2030 implied from diverse characteristics and growth of cities."** *Nature Sustainability* 2: 748–754. *Cover article of August edition of Nature Sustainability.*

RESEARCHER SPOTLIGHT

Tianguang Lu
Postdoctoral Fellow



As a young boy, Tianguang Lu idolized his electrical engineer father, and his career path commenced accordingly. "I was deeply influenced by him," says Lu, a postdoctoral fellow at the Harvard-China Project. "In the beginning, I hoped to follow in my father's footsteps to make my contribution to the electric power industry."

But as Lu progressed in his graduate studies, he fell in love with research. "Although sometimes there was pressure when I ran into a bottleneck," he says, "after I solved the problem, I felt a great sense of accomplishment." As his work advanced to the study of regional energy systems, he began to realize that he could also incorporate fields beyond electrical engineering, employing elements of data mining methods such as machine learning to better divine critical information as well as economic methods like game theory to help explore operation and market interactions between different regional energy systems.

He sees this same kind of interdisciplinary approach at work at Harvard-China Project. "Here, you can collaborate with scholars from many fields—including economics, environment, and energy," he says. Which helps, he notes, because so much of these topics are inherently intertwined. He offers the example of his current research, which is focused on the integration of low-carbon, low-emission power generation into India's power systems, and conducted under the leadership of HCP Chair Michael McElroy, who has expertise in air pollution, greenhouse gases, and climate, and in collaboration with current Ph.D. student Peter Sherman and HCP associate Xinyu Chen, both of whom focus on climate and energy.

Specifically, Lu says, his work on India seeks to better understand "how the combination of wind and solar can meet the future power demand, because India's population will grow very fast in the future." Lu's analysis has found that while some studies on Indian energy systems conclude that solar power will dominate the future of renewable energy in the country—mostly due to the existing rich solar resources—the reality is more complex. "Yes, at a lower level of renewable penetration, the power sector did favor solar investment," Lu says of his research findings. "But a higher penetration of renewables will favor wind power, because there is less variability from wind power, and wind will have a greater capacity factor"—the ratio of energy produced by a system relevant to its theoretical maximum.

This kind of state-level renewable integration that the India project is attempting, Lu says, is a monumental challenge with an equally monumental potential payoff. "It offers a big opportunity to solve various problems like greenhouse gas emissions and pollution," he says. "The goal of my work is to understand how energy systems can integrate more renewables to let the world be more green."

Lu's career has taken a more academic path than his father's, he notes. But he and his father still talk shop. Lu has his analytical perspective of engineering. "And I often speak to him about the practical aspect," he says.

By Dan Morrell

HARVARD-CHINA PROJECT
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哈佛大学中国项目新闻通讯

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哈佛大学中国项目位于哈佛大学John A. Paulson工程与应用科学学院，我们的“中国2030年/2050年：未来的能源与环境挑战”课题项目获得了哈佛全球研究基金的鼎力赞助支持。

中国环境与发展国际合作委员会2019年度会议

2019年6月上旬，哈佛中国项目主席Michael McElroy教授与项目执行总监Chris Nielsen出席了中国环境与发展国际合作委员会（“国合会”）在杭州举行的年度会议。国合会是最高等级的国际咨询委员会，向中国国务院和副总理韩正提供环境与发展相关事务的政策咨询。会议由中国生态环境部李干杰部长、中国气候变化事务特别代表解振华先生，以及来自联合国机构和西方国家政府的相关主管官员共同主持。

年会讨论的议题包括：按照《联合国气候变化框架公约》之巴黎气候协定提高气候行动的国家标准并加快推进行动进程（正式名称为“国家自主贡献”）的必要性，有必要使一带一路倡议相关投资与全球深度脱碳目标保持一致，以及2020年将由中国主办的下一届联合国《生物多样性公约》缔约方大会。出席国合会年度会议使哈佛大学中国项目有机会在中国高层决策咨询讨论会中直接向决策者介绍我们的研究成果，从而突显出独立研究在帮助决策者理解和应对中国环境与气候风险中的作用。同时，参加这次会议也有助于加强哈佛大学中国项目与中国及世界其他国家和地区主管环境与发展的高层决策者和意见领袖之间的联系。

中国环境与发展国际合作委员会供图

James Hammitt教授，版权：Claudio Cambon，哈佛大学环境中心/Adobe图片库

研究焦点

James Hammitt教授关于环境健康风险价值评估的研究

每个社会都需要回答一个问题，即控制污染和规避相关的健康风险到什么程度才最合适。答案显然不会是100%，因为当前科技的局限性，至少在政策相关的短时期内不可能做到。随着污染程度不断下降直至接近于零，继续降低污染的边际成本也会随之不断上升并最终超出合理的范围。因此，在污染控制到一定程度后，将有限的社会公共资源投入到其他成本收益比更高的政策上才更为明智。

成本收益分析可以将控制污染的所有正面影响（健康收益）和负面影响（控制污染的成本）全部换算成统一货币单位进行比较，是用来计算污染控制合理程度的一个标准工具。降低死亡风险的货币价值，即统计生命价值（VSL），则是完成这项分析的关键数据。

哈佛中国项目旗下关于环境健康风险及其在中国社会的价值的研究，一直由哈佛大学T. H. Chan公共卫生学院经济学与决策学教授、哈佛风险分析中心主任James Hammitt领衔，已逾15年。

Hammitt教授有关中国统计生命价值的最新研究在今年上半年发表于Journal of Risk and Uncertainty期刊，共同作者包括哈佛中国项目的新老成员耿方立，郭晓琪及Chris Nielsen。研究采用的是哈佛中国项目和北京大学于2005年和2016年在中国成都收集的跨学科的、严格抽样的住户调查数据。

一般来说，统计生命价值随着人均收入的增长而增长，但是增长率是多少呢？。相比其他的国际文献，Hammitt教授研究的独特之处在于，它用同样的调查方法、对于同样的研究对象人群、但在不同的时间进行的调查数据来计算统计生命价值。研究发现统计生命价值对于收入的增长率远高于大部分早期研究的计算结果，用经济学术语来说，就是统计生命价值的收入弹性接近于3。

实际上，该研究并未完全解释统计生命价值迅速增长的原因，除了收入增长之外，可能还有其他社会变化的因素。但无论如何，在考虑通过增加新投资、出台新政策来减轻污染时，中国的决策者们都应该认识到，民众眼中的人身健康与安全价值会继续快速上升。在这种趋势之下，任何新政策都应该把公众健康放在更重要的位置。

在污染控制到一定程度后，将有限的社会公共资源投入到其他成本收益比更高的政策上才更为明智。

该研究的第二项发现则涉及方法论。基于“意向性调查”的研究存在一个问题：调查对象对于小的概率变化的理解有限，因此很难确定其价值。通过询问被采访人对两个不同的风险变化的价值评估，该研究可以检测被采访人回答的内在逻辑连贯性，从而找出真正理解了调查问卷问题的被采访人。使用这个人群（样本足够大）的数据计算出的统计生命价值是使用所有被采访人数据计算出的统计生命价值的两倍。这说明其他基于全部调查样本（如大部分研究文献所做）得出的统计生命价值VSL估值有可能被低估了一半。

哈佛中国项目网站可免费下载本研究论文：*Hammitt, James K., Fangli Geng, Xiaoqi Guo, and Chris P. Nielsen. 2019. “Valuing mortality risk in China: Comparing stated-preference estimates from 2005 and 2016.” Journal of Risk & Uncertainty 58 (2-3): 167–186.*

秋季学期活动回顾

2019年秋季学期，哈佛中国项目主办了多场研讨会，并参与协办了一系列其他活动。

九月份，哈佛大学中国项目举办了秋季的第一场研讨会。演讲人吕瑛英是哈佛大学设计学院博士生，她也即将成为哈佛大学中国项目研究团队的新成员。步行是一种环保和健康的交通方式。吕瑛英以“中国步行文化”为题，探讨了步行如何通过降低交通能耗和减少排放来改善城市环境。

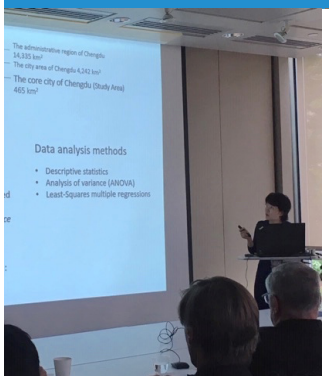
十月份，麻省理工学院城市研究与规划系房地产开发和创业学副教授郑思齐，作了题为“中国空气污染的社会成本”的报告。她关注中国城市空气污染背后更广泛的社会成本，阐述了空气污染对城市社交活动及其所承载的社会互动，以及都市人主观幸福感的负面影响。

清华大学环境学院副教授段凤魁研讨讲座的主题为“中国雾霾的颗粒物污染特征和混合状态"，其工作探究了北京冬季严重雾霾期间空气中细微颗粒物的化学组成，虽然大气中细微颗粒物浓度年均值自2013年以来有所下降，但北京冬季依然会出现严重雾霾天气。

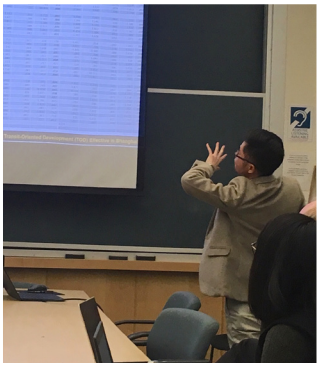
十一月份，哈佛大学中国项目博士后研究员陈法安作了题为“出行习惯与城市环境：上海城市轨道交通系统发展的成效”的报告，研究测试了人们的出行习惯到底是受城市轨道交通建设的影响大，还是更受制于居民个人的选择偏好。

十二月份，由哈佛肯尼迪政府学院环境与自然资源项目协办，哈佛肯尼迪政府学院博士后研究员Cecilia Han Springer作了2019年秋季学期的压轴报告，主题为“中国碳市场的机遇与挑战：从模型到现实”，她的工作对政策实施过程中的阻碍进行了模拟分析和实地调查，以此来探讨中国碳市场是否能够产生成效。

此外，哈佛风险分析中心在九月份举办了为期两天的题为“风险测评、经济评估与决策“的研讨会，以致敬哈佛大学T. H. Chan公共卫生学院John S. Evans教授。两天的研讨会探讨了风险测评与经济的交汇点以及主流专家的重点论文，相关专家包括Evans教授和其他哈佛中国项目的新老合作者。







陕西省西安市，位于一带一路东端起点

世界银行地图：当代一带一路全图

研究焦点

太阳能推动“一带一路”倡议的绿色发展

研究者量化分析了区域可再生能源潜力

科学家们于2019年6月27日在Joule期刊发表的研究论文指出“一带一路”倡议(BRI)覆盖地区的太阳能潜力极大，只需不到百分之四的太阳能潜力极值就能够满足2030年“一带一路”倡议的电力需求。论文就一带一路参与国在发展经济的同时降低对化石燃料的需求提出了可行的建议，也是首次对该地区可再生能源潜力进行量化的研究。

中国政府于2013年提出了旨在促进区域发展和联系的“一带一路”倡议。“带”代表丝绸之路经济带，指联结古代亚洲和欧洲的丝绸之路。“路”是指21世纪联结中国、东南亚、南亚和北非的海上丝绸之路。截至目前，已经有亚洲、欧洲、非洲、南北美洲和大洋洲的120多个国家响应并加入了倡议。

一带一路项目主要投资和建设诸如铁路、建筑和发电厂等基础设施。然而，由于大部分项目需要消耗大量的能源，因此导致了高污染高排放。此外，参与一带一路的大部分国家都是发展中国家，相当一部分地区尚未通电，但随着经济的发展，预计这些国家对电力的需求将会不断增长。

论文作者之一、清华大学的鲁玺教授认为：“如果我们继续依赖化石燃料作为能源，不仅是短期，在未来几十年都会向大气排放出大量的二氧化碳，

本研究揭示的太阳能发电潜力和合作机遇为"一带一路"国家摆脱传统高碳排放发展路径，谋求低碳发展创造了机遇。

这不是可持续的发展。如果我们想要达成《巴黎气候协定》设立的节能减排目标，就必须使用可再生能源。”

由于许多一带一路国家，尤其是西亚和南亚国家的日照时间长，强度大，鲁玺和研究团队其他成员决定评估该部分地区的太阳能资源。他们挑选了66个地理位置相邻的“一带一路”参与国，建立了空间模型并用高分辨率的数据来计算太阳能潜力。

研究团队首先评估了适合建造太阳能发电站的区域，这些区域（不包括森林和农业用地）太阳辐射充足而土地价值较低。然后，团队在最大化发电量的基础上，计算出太阳能电池板的间隔距离和排列密度。最后，在考虑了诸如遮挡阴影和温度等影响太阳能电池板性能的限制因素后，团队计算出了这些区域逐小时的发电量。

鲁玺说：“我们的模型考虑到了各种影响因素，对该地区的太阳能潜力进行了综合分析。我们还计算了每小时的太阳能发电量，比之前估计的月度发电量数据更加精确。”

研究团队发现这些国家年发电量448.9万亿千瓦时，是2016年

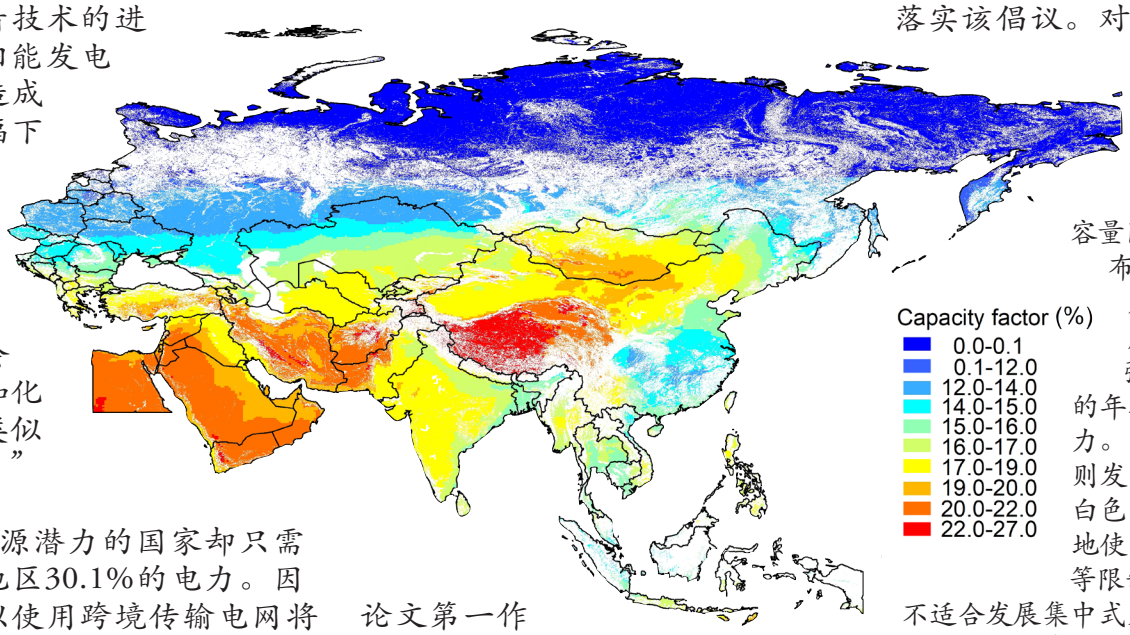
自身电力需求量的41倍。只需转化该地区3.7%的太阳能即可满足当地2030年的电力需求。而要做到这一点，则需要投资11.2万亿美元以及占用面积88,426平方公里的土地。

“投资数额很大。”论文另一位联合作者、哈佛大学的Michael McElroy教授说，“但是如果投资建厂，接下来太阳能产生的电力几乎没有边际成本。而且随着技术的进步，太阳能发电场的建造成本会大幅下降。我们预计太阳能成本在十年内就会下降到和化石燃料类似的水平。”

70.7%能源潜力的国家却只需消费该地区30.1%的电力。因此，可以使用跨境传输电网将电量过剩地区的太阳能电力出口至短缺地区，将太阳能发电的效益最大化。要做到这一点，国际合作必不可少。

鲁玺认为：“虽然这并不容易，因为每个国家的发展优先项各不相同，但是“一带一路”给大家提供了一个机会，建立了一个国家和国家、组织与组织、行业与行业之间开展合作的平台。许多基金和银行也致力于推动“一带一路”倡议的绿色发展，愿意提供资金支持。”

由于“一带一路”参与国跨越多个时区和气候带，跨境传输电网也有助于降低各个地区太阳光照减少时发电量难以与电力需求相匹配的影响。



图注：“一带一路”地区光伏发电容量因子空间分布。容量因子反映了综合考虑技术、光照强度等因素后的年均光伏发电潜力。容量因子越高则发电潜力越大。白色区域为依据土地使用类型、坡度等限制条件排除的不适合发展集中式光伏发电的区域。图源陈诗。

论文第一作者之一、清华大学博士生陈诗认为：“跨境传输电网的优势符合“一带一路”五大合作重点之一的“设施联通”理念。在全球能源互联网(GEI)的大环境下，太阳能发电将迎来跨国甚至跨地区电力联通浪潮下新的发展机遇。”

论文联合作者、清华大学环境学院的郝吉明教授认为：“研究分析得出的太阳能潜力与合作机会对“一带一路”参与国来说是个摆脱传统高碳密集型发展路径跃入低碳发展模式的好机会。未来确实有可能做到在不增加碳排放的前提下实现经济增长。”

McElroy教授说：“我们希望这篇论文能够推动一带一路的绿色发展，能以更好的方式来落实该倡议。对此我很乐观。”

引文: *Shi Chen, Xi Lu, Yufei Miao, Yu Deng, Chris P. Nielsen, Noah Elbot, Yuanchen Wang, Kathryn G. Logan, Michael B. McElroy, and Jiming Hao. 2019. “The potential of photovoltaics to power the Belt and Road Initiative.” Joule, 3, Pp. 1-18.*

细胞出版社，Yvaine Ye撰

首届摄影大赛

2019年秋季学期，哈佛中国项目举办了首届摄影大赛，收到了近60份投稿作品，角逐三个类别的奖项：中国自然风景、中国能源与环境、中国城市景观。投稿作品来自于工程与应用科学学院、哈佛学院、医学院、设计研究院、T. H. Chan公共卫生学院和肯尼迪政府学院。封面照片、图左（摄影者：马小虎，哈佛文理学院经济系本科2021届学生）；其他作品请见哈佛中国项目网站。

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Gao, Meng, Peter Sherman, Shaojie Song, Yueyue Yu, Zhiwei Wu, and Michael B. McElroy. 2019. **"Seasonal prediction of Indian wintertime aerosol pollution using the Ocean Memory Effect."** *Science Advances* 5 (7): eaav4157.

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Srinivasan, Sumeeta, Chenghe Guan, and Chris P. Nielsen. 2019. **"Built environment, income and travel behavior: Change in the city of Chengdu 2005-2016."** I*nternational Journal of Sustainable Transportation.*

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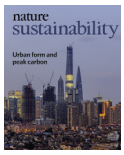
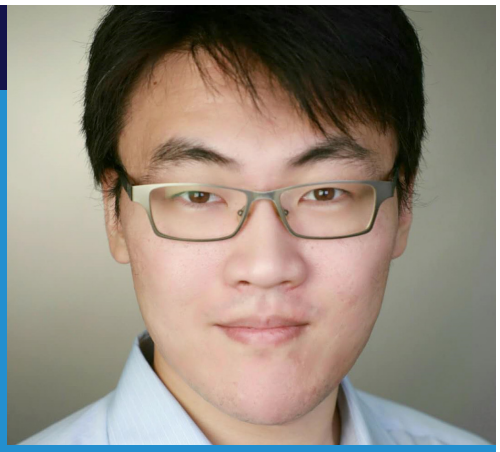


Wang, Haikun, Xi Lu, Yu Deng, Yaoguang Sun, Chris P. Nielsen, Yifan Liu, Ge Zhu, Maoliang Bu, Jun Bi, and Michael B. McElroy. 2019. **"China's CO2 peak before 2030 implied from diverse characteristics and growth of cities."** *Nature Sustainability* 2: 748–754.
Cover article of August edition of Nature Sustainability.

本期人物

博士后研究员：吕天光



吕天光从小就视电气工程师父亲为偶像，并在父亲的影响下走上了专业道路。他回忆道："我从小深受父亲的影响。起初，我只是想追随父亲的脚步在电力行业做出成绩。"

但在后来的研究生学习过程中，吕天光却渐渐爱上了科研。"尽管遇到研究瓶颈时压力很大，但是问题一旦解决，就能带给我极大的成就感。"随着研究工作深入到区域能源系统领域，吕天光开始意识到还可以将电气工程以外的领域整合进来，比如运用机器学习等数据挖掘方法推导出关键信息，也可以运用博弈论等经济学方法来探索不同区域能源系统间运行和市场的互动关系。

吕天光觉得哈佛中国项目进行的正是这样的跨学科研究。"在这里你可以和来自经济、环境、能源等各领域的学者合作交流，由于很多研究课题本身就互为交织密不可分，因此这样跨学科的交流合作就非常有效。"譬如他自己目前正在做的印度电力系统低碳、低排放发电并网研究，就是由哈佛中国项目主席、空气污染、温室气体和气候专家Michael McElroy教授领衔，与主攻气候与能源的博士生Peter Sherman和研究员陈新宇合作开展的。

吕天光强调，他对于印度的研究工作是为了更好地了解"风能和太阳能发电如何满足人口增长迅速的印度未来的电力需求"这一课题。虽然目前某些相关研究得出结论认为，印度拥有充足的太阳能资源，未来太阳能发电将成为其可再生能源发电的主流，但吕天光分析后认为现实情况其实复杂得多。"是的，在低可再生能源渗透率的情况下，电力系统会优先选择投资光伏发电；但是在高可再生能源渗透率的情况下，电力系统就会优先考虑投资风能发电，因为风能的稳定性和容量因子（发电量与最大额定容量的比率）都较高。"

印度项目目前所尝试的这种国家级的可再生能源并网是一项前所未有的巨大挑战，但同时也蕴含着巨大的效益。"这有可能解决温室气体排放和污染等各种问题。我的研究目标是去了解能源系统如何能与更多可再生能源实现并网，从而让地球环境更加绿色环保。"

同父亲相比，吕天光的职业路径更偏学术，但父子俩依然经常进行专业探讨。对工程吕天光有自己的分析角度，"但我也经常和我父亲讨论工程和业务实践的话题。"

英文原文由Dan Morrell撰写