HARVARD-CHINA PROJECT
on Energy, Economy and Environment

CHINA PROJECT NEWSLETTER

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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."

China Project Research

Environmental Impact of Electric Vehicles in China? It Depends on How They Are Charged

China Project research offers a strategy for reducing CO_2 emissions and improving air quality with electric vehicles in Beijing

Electric vehicles play a key role in China's plan to improve air quality and reduce CO_2 emissions but, with the majority of China's electricity still coming from coal-fired power plants, many question just how effective this strategy is.

Now, researchers from Harvard University and Tsinghua University in Beijing found that private electric vehicles in China can have a positive effect on CO_2 reduction if owners can be incentivized to slowly charge vehicles during off-peak hours, allowing for more effective use of wind-generated power. Quickly charging vehicles in the higher energy "fast mode", on the other hand, can be counterproductive.

Meanwhile, buses and taxis in China make a significant contribution to NO_X emissions, a major precursor for air pollution. The team determined that electrifying the bus and taxi fleet offers the most effective option for improving air quality.

The research is published in *Nature Energy.*

"This research offers a more nuanced strategy for reducing CO_2 emissions and improving air quality in China," 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 the Department of Earth and Planetary Sciences and co-author of the research.


ELECTRIC CHARGING STATION IN BEIJING / WIKIMEDIA

"If people were incentivized to wait until evening and charge their vehicles in the slow-charge mode, the power load could take advantage of wind energy available during off-peak hours"

"It is critically important that electric vehicle charging is managed properly to maximize the benefits of renewables," said Xinyu Chen, Research Associate in Environmental Science and Engineering at SEAS and co-author of the study.

The researchers used real-time power demand data and driving patterns for Beijing and its suburbs to develop a comprehensive model of the energy system. They found that how electric vehicles are charged — whether in the low-energy slow mode or high-energy fast mode — plays a significant role in the integration of wind energy. Typically, vehicle charging in the 30-minutes or less fast mode occurs during hours of peak power demand. As a result, peak power demand is increased, triggering additional coal generators to come online. With these generators operational at night, the opportunity to take advantage of available wind power is reduced.

"If people were incentivized to wait until evening and charge their vehicles in the slow-charge mode, which takes hours, the power load could take advantage of wind

ELECTRIC BUS IN SHANGHAI AT A CHARGING STATION / WIKIPEDIA

energy available during off-peak hours," said Chris P. Nielsen, Executive Director of the Harvard China Project and co-author of the study.

In terms of lowering air pollution, the researchers found that the gas- or diesel-fueled fleet of public vehicles — about 30,000 buses and 66,000 taxis — is responsible for nearly 20 percent of total NO_X emissions, equivalent to the contribution from 8.2 million private vehicles. Electrifying the fleet of buses and taxis in Beijing would significantly reduce total NO_X emissions and increase air quality.

"Electrifying the public fleet and introducing incentives to charge personal electric vehicles at off-peak times would be the most effective strategy to reduce NO_X and CO_2 emissions in Beijing," said McElroy. "This strategy could also be applied to cities across the world that have a significant source of electricity from coal."

The research was co-authored by Hongcai Zhang, Zhiwei Xu, and Jiajun Lv. It was supported in part by the Harvard Global Institute and the Hui Fund of the Ash Center of the Harvard Kennedy School of Government.

By Leah Burrows, SEAS Communications

Paper cited:
Xinyu Chen, Zhiwei Xu, Chris P. Nielsen, and Michael B. McElroy. 2018. "Impacts of fleet types and charging modes for electric vehicles on emissions under different penetrations of wind power." *Nature Energy*, 3, Pp. 413-421.

Summer RAs in China 2018

This summer, a select group of Harvard undergraduates will be hard at work in China, tackling a variety of research projects ranging from the effects of arsenic contamination of groundwater, to the policy design of banning residential coal use in rural areas around Beijing, to the climate implications of electric vehicles. These environmental research projects are part of the "China's Environmental Challenges 2018: Summer Undergraduate Research Assistantships in China" program offered by the Harvard-China Project and sponsored by the Harvard Global Institute under the "China 2030/2050 Initiative." The eight Harvard undergraduates will receive full funding to spend the summer in China—seven of them will work with professors at Tsinghua University in Beijing, while one will work with a professor at Chinese University of Hong Kong.

Last year, the China Project organized a more education-oriented summer program (also sponsored by the Harvard Global Institute), in which 30 Harvard undergraduates joined 80 students from China and other countries around the world for a two-week intensive summer program at the Tsinghua University School of Environment.

The Summer 2018 recipients' names and concentrations are listed below. More program details can be found at: *www.chinaproject.harvard.edu/summerprogram-2018*

· **Shannon Beattie**, Earth and Planetary Sciences and Environmental Science & Public Policy
· **Julia Henry**, Environmental Engineering
· **Andrei Iliescu**, Chemistry
· **Irene Lu**, Molecular and Cellular Biology
· **Aditya Mahadevan**, Physics
· **Andrew Pendergrass**, Physics and Mathematics
· **Caleb Ren**, Environmental Engineering
· **Katie Schluntz**, Economics

Recent Publications

Xinyu Chen, Zhiwei Xu, Chris P. Nielsen, and Michael B. McElroy. 2018. "Impacts of fleet types and charging modes for electric vehicles on emissions under different penetrations of wind power." *Nature Energy*, 3: 413-421.

Shaojie Song, Meng Gao, Weiqi Xu, Jingyuan Shao, Guoliang Shi, Shuxiao Wang, Yuxuan Wang, Yele Sun, and Michael B. McElroy. In Press. "Fine particle pH for Beijing winter haze as inferred from different thermodynamic equilibrium models." *Atmospheric Chemistry and Physics*.

Bo Zhang, Yaowen Zhang, Xueli Zhao, and Jing Meng. 2018. "Non-CO_2 greenhouse gas emissions in China 2012: Inventory and supply chain analysis." *Earth's Future*, 6: 103-116.

Zhaoxi Liu, Qiuwei Wu, Kang Ma, Mohammad Shahidehpour, Yusheng Xue, and Shaojun Huang. 2018. "Two-stage optimal scheduling of electric vehicle charging based on transactive control." *IEEE Transactions on Smart Grid*. DOI: 10.1109/TSG.2018.2815593

Jaume Freire-González and Mun S. Ho. 2018. "Environmental fiscal reform and the double dividend: evidence from a dynamic general equilibrium model." *Sustainability*, 10, 2.

Michael B. McElroy, Xinyu Chen, and Yawen Deng. 2018. "The missing money problem: Incorporation of increased resources from wind in a representative US power market." *Renewable Energy*, 126: 126-136.

Jing Cao, Mun S. Ho, Yating Li, Richard G. Newell, and William A. Pizer. In Press. "Chinese residential electricity consumption estimation and forecast using micro-data." *Resource and Energy Economics*.

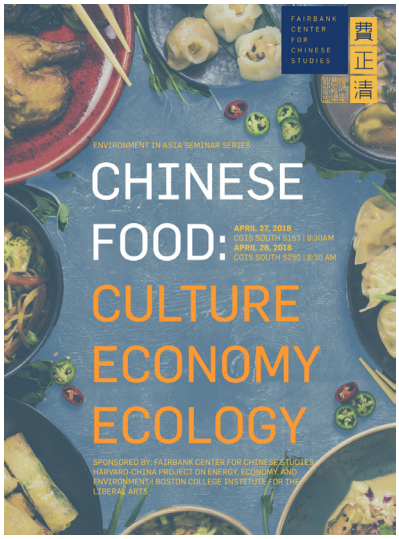
Qing Yang, Ji Liang, Jiashuo Li, Haiping Yang, and Hanping Chen. In Press. "Life cycle water use of a biomass-based pyrolysis polygeneration system in China." *Applied Energy*.

Xinyu Chen, Jiajun Lv, Michael B. McElroy, Xingning Han, Chris P. Nielsen, and Jinyu Wen. In Press. "Power system capacity expansion under higher penetration of renewables considering flexibility constraints and low carbon policies." *IEEE Transactions on Power Systems*.

KE TANG / HARVARD GAZETTE

Spring 2018 Major Events

On April 17, 2018, Liu Zhenya, former chairman and president of State Grid Corporation of China (SGCC), the world's largest utility company, and currently the chairman of the Global Energy Interconnection Development and Cooperation Organization (GEIDCO), gave a university-wide public lecture titled "The Art of Energy Revolution: From Ultra High Voltage Power Grids to Global Energy Interconnection" to an audience of over 200 people at Harvard Law School. Liu proposed a network of ultra-high voltage transmission lines to interconnect electric grids across much of the world by 2050 to 2070, accelerating expansion of global renewable power by allowing it to be transmitted over far greater distances from sources to consumers . Followed by a lively Q&A and debate, the lecture was part of the Harvard-China Project's "China 2030/2050 Initiative" and was also co-sponsored by the East Asian Legal Studies Program at Harvard Law School; the Harvard Paulson School of Engineering & Applied Sciences; and the Harvard Global Institute. Liu and key representatives from GEIDCO met with China Project and SEAS faculty and researchers prior to the lecture to discuss Harvard research on wind power potentials, grid integration of renewable electricity, and flow battery technologies.



The Harvard-China Project co-sponsored and provided core funding for a two-day workshop in late April titled "Chinese Food—Culture, Economy, Ecology," organized by Prof. Zhang Ling of the Fairbank Center and Boston College and Dr. Elizabeth Lord, An Wang Postdoctoral Fellow at the Fairbank Center. International scholars from various humanities and social science disciplines were invited to present draft papers on topics ranging from the shifting relationship of food and power, to the role of Chinese scientists in China's GMO controversy, to soil pollution surveys in contemporary China. The workshop, part of the Fairbank Center's "Environment in Asia" series funded in part by the Harvard-China Project, drew full attendance and lively discussions, and will lead to further cross-disciplinary conversations and scholarship around the theme of food culture, economy, and ecology in China.

Does Climate Change Explain Declining Wind Power Potential in China?

To combat climate change, reduce air pollution, and establish greater energy independence, China has been pushing hard for a nation-wide transition to renewable energy, and is now home to the world's largest market for wind-generated electricity. The installed capacity for wind generation in China accounts for over one third of the global total. Yet a paper recently published in the Nature journal Scientific Reports and covered by the Washington Post found that climate change might be threatening wind power—one of the very strategies that countries are relying on to help them achieve the goal set forth in the Paris Agreement of keeping global temperature rise below 2 degrees Celsius. Tiffany Chan from the Harvard-China Project sat down with one of the co-authors of the paper, Ph.D. student Peter Sherman, to discuss the team's findings. The full interview is also available at the China Project's Medium page: www.medium.com/@harvardchina

Peter, you had a paper that was published in *Scientific Reports*. Can you tell us more–what is the topic of investigation?
Under the supervision of Professor [Michael B.] McElroy and Xinyu [Chen], we looked at wind variability in China over the past 37 years from 1979 to 2015. We used a NASA dataset, which combines model data with observations from stations, to see how wind has varied over these years and how it could affect wind power.

What are the results?
We found that there is a declining trend in wind speed over the past 37 years, particularly over the regions where a lot of wind farms in China already exist, mainly Western Inner Mongolia and northern China, where there are not only high wind speeds, but also environments that are suitable for installing wind turbines—so regions with the proper geographical features. We found a decrease in wind speed in these regions and it correlates really strongly with rising regional and global surface temperatures, which makes physical sense. We conclude that because there were these rising surface temperatures and decreasing wind speed trend, climate change probably had a pretty significant contribution to the decreasing trend and it could continue in the future.

Can you explain to us briefly how rising surface temperatures affect wind speed?
Basically, winds are formed by pressure differences. If there is high pressure in one area and low pressure in another, it's going to form wind. A lot of this is due to the temperature difference between land and sea. If temperatures are increasing over land more than they are over sea, then we would expect this temperature difference to shrink and wind speed to decrease along with that. That's what we think we are seeing here.

How do you think your finding might affect the planning of wind installations and the energy transition in China?
I don't think it should affect the planning. While these decreases in wind speed may be happening, wind power is still very important and should become a more dominant source of

energy in the future, because coal, we know, is not good for the environment. So while there may be decreasing potential for wind power, it's still very useful. An area of concern that China has is wind curtailment. Wind power is a variable source; when it's really windy and we don't use all the wind power, we don't have any way of storing that wind, so it's being wasted. What China, in particular, needs to work on is to develop some kind of storage, like a battery, in order to be able to store the extra wind power that is not being used.

Are the results what you expected?
There have been some other papers in the past that have talked about the decreasing wind potential in China, but we were particularly surprised by how strong the decrease was for these areas where there is great potential for wind—the greatest declines were actually in those areas, so that was pretty surprising for us.

"Wind power is obviously an important step going forward in terms of what we should do to protect the environment, and yet even something like this is affected by climate change. It is important to bear this in mind in the future."

Are there any future questions that your research raised?
What we are planning to do now is to look at climate models that project how wind speeds are going to change in the future to see if those models also demonstrate this declining wind speed trend and if that could affect wind power in China.

For some of our readers who might know little about this topic but are very concerned about the environment and climate change in general, especially with all these ongoing discussions about energy transition that is necessary to combat climate change, what is the one thing you want them to take away from this paper?
That climate change has broad implications for the energy system as a whole. Wind power is obviously an important step going forward in terms of what we should do to protect the environment, and yet even something like this is affected by climate change. It is important to bear this in mind in the future.

How did you get involved in this research?
In the winter of my junior year in college, I was looking for research projects to do over the summer. I looked up on Google the various professors who do research that I am interested in. I found Prof. [Mike] McElroy and reached out to him. He offered me a research assistant position with the Harvard-China Project over the summer, and I was really interested in it, so I took it right away. It worked out very well. That's also how I met Xinyu [Chen], who was a postdoc at the China Project.

How do you find the transition from being a research assistant at the Harvard-China Project to being a Ph.D. student at Harvard? What made you decide to come to Harvard to get a Ph.D.?
I found the transition very easy: it was basically doing the same sort of work that I was doing over the summer. I have always planned on going to Harvard, and I think my work with Mike and Xinyu really confirmed that. It made me realize how collaborative the environment is here; everyone is willing to help with your work and talk to you—I was really surprised by that. When I was applying for graduate schools, there were a few other options I had, but I just felt that the environment here was so collaborative and helpful that I felt it was perfect for me.

Paper cited:
Peter Sherman, Xinyu Chen, and Michael B. McElroy. 2017. "Wind-generated electricity in China: Decreasing potential, inter-annual variability, and association with climate change." *Scientific Reports* 7.

Peter Sherman is currently pursuing his Ph.D. degree in Earth and Planetary Sciences at Harvard University. He received his undergraduate degree in physics from Imperial College London, U.K. He is interested in a variety of topics, particularly green technology and how weather might affect it, and climate models in general.

Scientific Reports Names Harvard-China Project Paper Top 100 Most Read Articles in 2017

The paper discussed in this section, "Wind-generated Electricity in China: Decreasing Potential, Inter-annual Variability and Association with Changing Climate," was named one of the 100 most read articles in earth sciences of 2017 in the *Nature* journal *Scientific Reports.*