HARVARD-CHINA PROJECT
on Energy, Economy and Environment

# HARVARD-CHINA PROJECT NEWSLETTER

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*Cover: Bipeng Ditch, Sichuan Province, by Owen Spencer*

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."

# LETTER FROM THE EXECUTIVE DIRECTOR

## The Harvard-China Project During COVID-19

Like most people, those of us in the Harvard-China Project were relieved to turn the page on 2020 with new hope for 2021. Most importantly, the pandemic has disrupted our researchers' scholarly and private lives.

This has included those here at Harvard forced to hole up in crowded apartments when the shutdown began, but also a cohort of invited researchers who have had to put plans to join us in Cambridge on hold.

As in other programs, the pandemic has also constrained engagement with our broader community. This importantly includes the happenstance encounters with interesting people thinking interesting things—while milling about after classes or seminars, but as often while getting coffee or in the gym—an underappreciated driver of fresh research perspectives and one of the most enjoyable rewards of studying and working at a university.

Still, despite the disruptions, the Harvard-China Project has in many ways made its way through the pandemic better than expected. Our research productivity has not slowed (see Publications, page 8), in part because moving online has fostered research progress in some ways even as it has impeded it in others. Spending hours on Zoom with less-than-perfect home internet connections brings annoyances now familiar to all, but also opportunities and advantages that shouldn't be taken for granted. For an international research program like ours, routinization of virtual interaction has raised the frequency of in-depth research discussions with collaborators in China and beyond, and made participation in seminars and conferences with colleagues literally across the planet a remarkably standard aspect of our weekly research lives.

We will also acknowledge relief about shifts in political winds affecting our work. It's good to have a U.S. government that appreciates science and the role climate change plays in our future; that engages internationally with rational forethought; and that recognizes that students and researchers, wherever they come from, are almost always just curious and diverse individuals engaging with others to better understand the world around us and the future we face together.

*— Chris P. Nielsen, Executive Director*

# INTERNATIONAL FORUMS

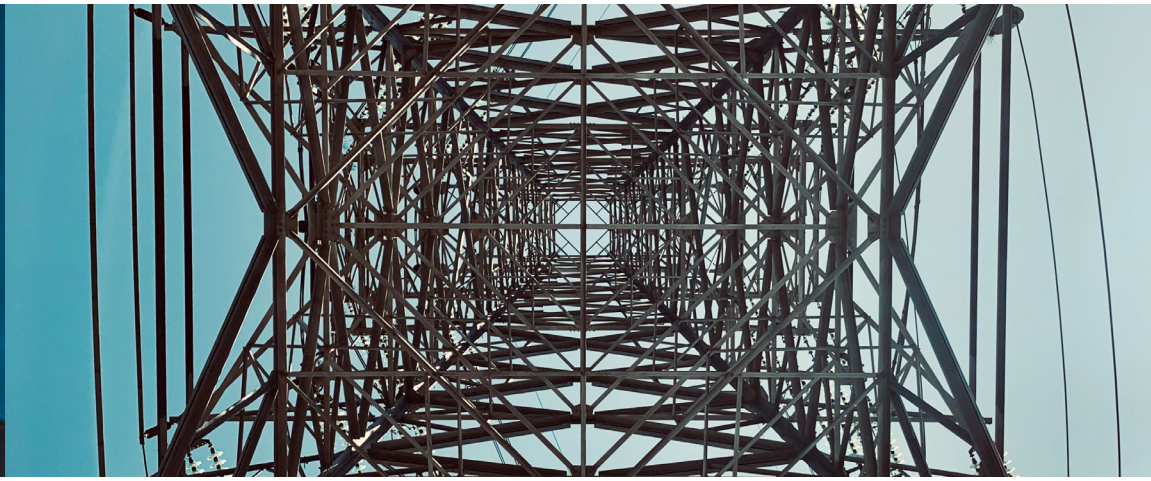
## China Council for International Cooperation on Environment and Development (CCICED)

Professor Michael McElroy, chair of the Harvard-China Project, continued his active membership in CCICED, the highest international advisory body providing policy recommendations on environment and development to China's State Council. The shift of CCICED to online meetings and conferences due to the pandemic in fact increased opportunities to inject lessons from Project research into deliberations of Chinese and global policy actors on climate and development challenges, and importantly to highlight the value of late-breaking academic research findings to forward-thinking policy solutions.

Most importantly, McElroy provided written inputs into the CCICED's "Interim Recommendations for the 14th Five Year Plan," and debated these recommendations with other Council members in formal sessions. Among his recommendations were: 1) a five-part case for accelerated electrification and decarbonization of China's power sector, highlighting potentials for offshore wind power, gasification and combustion of biomass with carbon capture as a carbon-negative power source, and production of hydrogen by electrolysis using renewable power (so-called "green" hydrogen); and 2) broadening China's national carbon emission trading system (ETS) into a hybrid carbon pricing policy, incorporating a carbon tax on non-ETS sectors. All elements were drawn directly from recent or ongoing China Project research.

In September, McElroy joined the review of CCICED's ten latest policy research studies, and in October presented new Project findings on prospects for green hydrogen in China, India, and Japan in the "Virtual Forum on the Hydrogen Economy." An international conference co-sponsored by CCICED and the International Institute for Sustainable Development, the meeting led to subsequent consultations of China Project researchers with green hydrogen industry leaders from both China and Japan that may evolve into new strategic partnerships.

Dr. Mun S. Ho, Harvard-China Project



## RESEARCHER Q&A

# "The Politics and Economics of Electricity Reform and Environmental Protection in China" with Mun S. Ho, Visiting Scholar

*Mun S. Ho, Visiting Scholar with both the Harvard-China Project and Visiting Scholar with the Resources for the Future, is an economist working on productivity measurement and environmental policy analysis. His two-part Q&A series on electricity reform in China can be found on our website, and an excerpt from part two is below:*

The simplest way to use less electricity is by improving energy efficiency, that is, getting the same amount of light from less kWh, the same air conditioning from less kWh, or the same production from machines in our factories from less kWh. Another way is what is known as "demand management." Society's use of electricity varies enormously by hour and season, as we noted in part 1: there are peak hours where the demand is 50% higher (or even more) than the low hours of a particular day. We currently deal with this by building enough capacity to meet the peak, though this leaves a lot of capacity idle during most hours of the year. Demand management means trying to shift demand across the hours so that the peak is lower, and thus the maximum capacity is lower; therefore, all units get used more often, ultimately lowering average costs.

To develop policies to address these demand-side issues, we need to understand the structure of demand by both businesses and households. We must learn how people use power; how demand reacts when we change prices; and what the future demand will be when we introduce new technologies. This includes exploring how we can change the price structure to encourage people to use power at different hours. Some of our research is devoted to this, learning about demand characteristics.

One project Jianglong Li [Professor at Xian Jiaotong University and an Associate of the Harvard-China Project] and I have is to explore how the so-called "block-pricing system" in Zhejiang province affects household use of electricity. In the old days, like many places in the US today, households were charged a flat rate no matter how much they use. However, since 2012, Zhejiang has a system where the price per kWh rises when a household consumes more than a certain number of kWh per year, i.e., they move to a higher priced block. The idea behind such block pricing systems is to ensure that even poor families can afford some minimum amount of electricity, while presumably wealthier consumers pay higher prices as a means to encourage conservation. The questions that researchers in many countries are trying to answer include: do these block pricing systems actually reduce the use of electricity? Are most people aware of the prices they pay? Do people know whether they are near the use threshold where the price jumps? And even if they know the correct prices, do they reduce electricity use?

**"To develop policies to address these demand-side issues, we need to understand the structure of demand by both businesses and households."**

One might think that these should be easy questions to answer. Why not just compare the electricity consumption in 2011 versus 2012? That is not feasible because even if we have power consumption data, many things may have changed between 2011 and 2012: the economy has grown, or people are wealthier, or people could have moved in or out of the household. We have data on the daily use of electricity in a sample of houses in all areas of the province, but unfortunately, we do not have information on how many people live there, what their incomes are, or what electrical appliances and devices they have.

We had to do some careful comparisons using our data. The system charges 53.8 fen (Chinese cents) per kWh for usage less than 2760 kWh per year; 58.8 fen for 2760-4800 kWh per year; and 83.8 fen for usage greater than 4800 kWh per

*continued on page 4...*

year. These prices were chosen by the government so that they ended with about 80% of households in the first block, 15% in the second block, and 5% in the top block. Most urban people in Zhejiang live in apartment buildings, so the electricity consumption is much lower than in more typical houses in the U.S. (For comparison purposes, in my house with 3 kids I use 1200kWh per month during the summer and 400 kWh during spring.) The interesting thing about the Zhejiang system is that there is a cell-phone app which people can use to check how much electricity they have used during the year. The year-to-date total is also given in the monthly bill. Consequently, we argue that there is no serious barrier to obtaining information about how close a family is to the end of each price block.

In research with Yating Li (at that time a Ph.D. student at Duke University), and her professors at Duke and Jing Cao at Tsinghua University, we used household data where we do have information on household size, income and appliances, but not data on daily use (only annual electricity use). We combined this data with temperature data, and estimated that annual demand for electricity depends on prices, incomes and appliances owned. We found that when people have more wealth, they buy more appliances and run their air conditioners and other equipment more often, leading to a significant increase in electricity use. However, this "income elasticity" diminishes as we go up the income scale; that is, the impact is larger when the poor get more income. When the rich get more income, they use only a bit more electricity. We estimated that the income elasticity falls from 0.28 to 0.14 as income rises. Using these estimates, combined with historical data, we project future demand by households based on estimates of growth of future incomes. We project that demand by 2025 may be 85-143% higher than the demand in 2009 as a result of higher appliance ownership and higher use of individual appliances.

*Page 3: Image by Xiang Xio*

## RESEARCHER SPOTLIGHT

### Xi Yang
### Visiting Scholar

As a college student hailing from Nanjing, China, Xi Yang was up to something a bit atypical for a young woman at the time, but so familiar in other circles. "Like every Silicon Valley boy," says Yang, a visiting scholar at the Harvard-China Project and associate professor at China University of Petroleum Beijing, she was "dreaming of having the best algorithm." That fixation on excellence took Yang to several contests for her energy systems models, where she always seemed to have the best of everything—the technology, the algorithm—but one thing stumped her. It was just as the 13th annual conference of the UN Framework Convention on Climate Change was wrapping up when a judge asked, "How does this technology contribute to society and meet community demand?"

That question stuck with Yang throughout her bachelor's degree work on electronic information and engineering at Tsinghua University and then at Mines ParisTech for a master's degree in advanced energy management before returning to Tsinghua for doctoral work. That research was also in management, but with a slightly different focus. Yang conducted her research at the Institute of New Energy Technology.

Now, at the Harvard-China Project, Yang collaborates with senior economist Mun S. Ho to expand her research to capture social impacts in her energy modeling through examining regional impacts upon population segments of differing incomes. Yang asks, "How does technology influence behavior and the public's energy use?" At the same time, she is also developing models of natural gas distribution and demands for and use of hydrogen produced with renewable power, intersecting with interests of other researchers in the Project including Chris P. Nielsen and Prof. Michael B. McElroy. Yang has welcomed the crossover with scholars from different disciplines and the opportunity for boundary-pushing feedback as afforded through her role at the Project. Her colleagues sometimes pick up on nuances that Yang had not prior considered. "Researchers here are very open-minded, shar[ing] their opinions on interdisciplinary topics," she says. "That's very inspiring for engineers."

Still lodged in her mind are that judge's words from her early forays into energy systems modeling. She constantly seeks to humanize her data and ground-truth what she meticulously crafted on the computer—sometimes deep into the night, she says, when she feels inspired. "I've always cherished every cold winter night when I'm debugging." As such, she adapted her modeling to account for actual energy demands. "We are doing modeling trying to simulate the real world," she says, "But people's behavior, they just impact [us] the most."

Looking to the future, Yang hopes to keep searching for technological solutions for a zero emission society while here. She says, "Besides the precautionary principle, it is scientists' job to provide solid proof that is accessible for all." Yang hopes to improve how we model our way forward.

*Written by Liza Tarbell*


Traffic policies in China


Renewable energy in India

# STUDIES IN THE NEWS

## Traffic Pollution Policies Save Hundreds of Thousands of Lives in China

Over the past two decades, emissions from cars and trucks have become a significant source of air pollution in China. In the late 1990s, China began to implement policies to mitigate traffic pollution but the outcomes of those policies, especially on air quality and public health, have never been systematically evaluated.

Now, several researchers from Harvard—including Professor John Evans and doctoral student Ernani Choma of the Harvard T.H. Chan School of Public Health—joined a team led by Haikun Wang, Professor of Environmental Sciences at Nanjing University, in a collaborative study of the topic begun while Wang was a visiting scholar in the Harvard-China Project at SEAS.

Analyzing those policies using a framework that combines emission scenarios, air quality modeling, and population health risk assessment, the team found that pollution control policies in China reduced vehicle emissions by one-half to two-thirds compared to what otherwise would have occurred, and led to roughly 510,000 fewer deaths attributable to fine particle and ozone exposures in 2015.

The research was published in the *Proceedings of the National Academy of Sciences*.

"Our research showed that while the vehicle population and traffic congestion have grown quickly in China, strict control measures implemented by the government have limited the resulting emissions and brought huge benefits in avoided health impacts of air pollution across the country, especially in cities," said Chris Nielsen, Executive Director of the Harvard-China Project and a co-author of the paper.

*Research Cited: Haikun Wang, Xiaojing He, Xinyu Liang, Ernani F. Choma, Yifan Liu, Li Shan, Haotian Zheng, Shaojun Zhang, Chris P. Nielsen, Shuxiao Wang, Ye Wu, and John S. Evans. 2020. "Health benefits of on-road transportation pollution control programs in China." Proceedings of the National Academy of Sciences, Sept 2020, 201921271.*

## Renewable Energy Could Power Most of India by 2040

India has already committed to the ambitious goal of transitioning to 60 percent renewable energy in its electricity sector by 2030, but recent research from the Harvard-China Project, based in Harvard SEAS, found that the country could go even further with renewables and reduce overall energy costs.

In a paper published in *Nature Communications*, researchers found that wind and solar energy could meet 80 percent of anticipated electricity sector demand in India in 2040. The researchers found that achieving that level of reliance on renewable energy would reduce $CO_2$ emissions by as much as 85 percent and the overall costs for power by as much as $50 billion.

"We came to the striking conclusion that investments in renewables today could play an important role in reducing the overall energy costs in India in the future," said Michael McElroy, the Gilbert Butler Professor of Environmental Studies and senior author of the study. "This has clear policy implications for India's electricity sector in planning for a low-carbon future."

McElroy and the team, which included researchers from Huazhong University of Science and Technology in Wuhan and Tsinghua University in Beijing, developed a new model that integrated all the various components of India's electricity system to find the cheapest way to incorporate specific levels of renewables into the overall power grid.

The researchers scaled current levels of energy consumption to estimate electricity demand in 2040. Their model considered the hourly demand over the course of the year for five regions and broke down the most cost-effective power strategy for each. Nationwide, the team found that the most cost-effective strategy to reach 80 percent renewable energy by 2040 would require 58 percent wind and 23 percent solar with coal, hydro, nuclear, and gas filling in the gaps. The researchers estimated that this strategy wouldn't be significantly more expensive to implement than the Indian government's current 60 percent renewable goal and would result in operating cost $50 billion cheaper than the coal-dominated approach.

*Research Cited: Tianguang Lu, Peter Sherman, Xinyu Chen, Shi Chen, Xi Lu, and Michael B. McElroy. 2020. "India's potential for integrating solar and on- and offshore wind power into its energy system." Nature Communications, 11, 4750.*

*By: Leah Burrows, Harvard Paulson School of Engineering and Applied Sciences (SEAS)*

## RESEARCH BRIEF

# "Influence of Urban Form on Active Transport in Chengdu, China"

## Prof. ChengHe Guan and Prof. Ann Forsyth

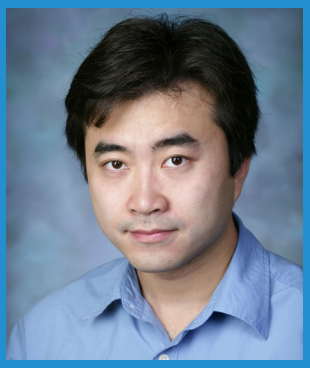
*ChengHe Guan is Assistant Professor of Urban Science and Policy, New York University Shanghai, and a postdoctoral research alumnus and current Associate of the Harvard-China Project on Energy, Economy and Environment based at the Harvard John A. Paulson School of Engineering and Applied Sciences. He earned his DDes at the Harvard University Graduate School of Design (GSD). Ann Forsyth is Ruth and Frank Stanton Professor of Urban Planning and Director of the Master in Urban Planning Program at GSD, and a faculty affiliate of the Harvard-China Project (HCP). The 2016 household survey in Chengdu was conducted by the HCP in collaboration with the Research Center for Contemporary China of Peking University. This summary for non-specialists was written by Professor Guan.*

Chinese cities are experiencing rapid growth and Chinese urban neighborhoods are undergoing substantial change. The government has launched a series of planning policies to promote active transport (walking and cycling), for example, the Ministry of Housing and Urban-Rural Development and the National Development and Reform Commission's guidelines and suggestions for building pedestrian and bike networks. However, the numbers of private motor vehicles in China continue to increase (123 million in 2015) and the share of active modes has continued to fall.

*Ann Forsyth, Harvard Graduate School of Design*

Active transportation should be examined in the context of multiple socio-demographic variables and urban-form variables at the neighborhood level, as well as by neighborhood types. Neighborhood types are important in China because nationally there are many parallels among developments from similar periods, and these neighborhoods mix a bundle of physical and social characteristics. By examining individual and neighborhood factors, this paper provides a more nuanced view of the evolving landscape of active transport in China.

Using a Harvard-China Project survey of 1,048 individuals conducted in 2016 in Chengdu—located in a carefully conceptualized typology of neighborhood forms—we analyzed the associations between individual and neighborhood characteristics and active or non-motorized transport behavior. Using several multiple logistic and multi-level models, we show how neighborhoods were categorized and the number of categories or neighborhood types affected the magnitude of the associations with active transport but not the direction. People taking non-work trips were more likely to use active compared with motorized modes in all neighborhood types. Neighborhood type was significant in models, but so were many other individual-level variables and infrastructural and locational features such as bike lanes and location near the river. Of the physical environment variables, floor area ratio (a proxy for density) was only significant in one model for non-work trips. Intersection density and dissimilarity (land use diversity) were only significant in a model for work trips.



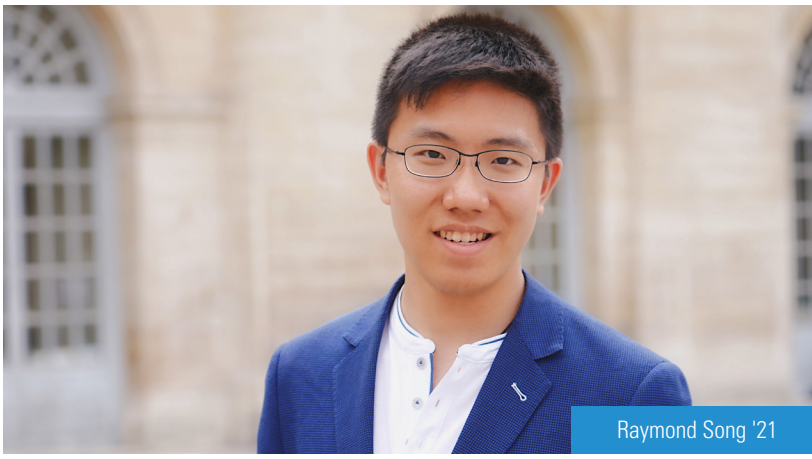
*ChengHe Guan, New York University Shanghai*

*Chengdu, Sichuan Province, is home to a 40-neighborhood active transport study. By Shu Qian*

This study shows that to develop strong theories about the connections between active transport and environments, it is important to examine different physical and cultural contexts and perform sensitivity analyses. Research in different parts of China can help provide a more substantial base for evidence-informed policy-making. Planning and design recommendations related to active transport need to consider how neighborhoods, built environments, and personal characteristics interact in different kinds of urban environments.

*Research Cited: ChengHe Guan and Ann Forsyth. 2020. "The influence of urban form and socio-demographics on active transport: A 40 neighborhoods study in Chengdu, China." Journal of Transport and Land Use.*


Jonathan D'Souza '23


Raymond Song '21

# UNDERGRADUATE RESEARCH

## "Incentives of Chinese Provincial Governments to Support Coal-Fired Power Plants" with ESPP concentrator Raymond Song '21

*Raymond Song, a senior Environmental Science and Public Policy concentrator based in Beijing, is working with Prof. Mike McElroy and Shaojie Song on his senior thesis. His Q&A is on our website and an excerpt is as follows:*

My senior thesis research aims to shed light on the fundamental drivers and tradeoffs behind China's ambitious climate pledges and its relevant energy policies. I hope the research will better explain the profound complexities surrounding China's somewhat conflicting attitude towards its climate and energy future. In September, China surprised the entire world with a commitment to achieve carbon neutrality before 2060 during the UN General Assembly. Yet, China's updated Nationally Determined Contributions to the Paris Agreement represent only an incremental step towards achieving this bold goal. On the one hand, China will raise its combined solar and wind installed power capacity to more than 1200 GW in 2030, compared with less than 500 GW by the end of this year; on the other hand, China's appetite for coal-fired power plants has only seemed to grow as economic recovery from COVID-19 has required a push from the industrial sector. As China charts a net-zero pathway for the future, I want to understand how these challenges will influence its low-carbon transition.

## "Effect of the COVID-19 Lockdown on Tropospheric Ozone Concentrations in the Indian Subcontinent" with Jonathan D'Souza '23

*Jonathan D'Souza, a Harvard sophomore, is working with Professor Mike McElroy, SEAS research associate Dr. Shaojie Song, and EPS graduate student Peter Sherman to study atmospheric chemistry in India. He participated in a project Q&A, found on our website - an excerpt is below:*

My current research investigates the effect of the COVID-19 lockdown on tropospheric ozone concentrations in the Indian subcontinent. India is of particular interest because of its quickly growing population, intense monsoon seasons, and emissions footprint as a transitional economy. While the virus forced many businesses to close down and industries to stall, it also provided researchers with a natural experiment to understand how the environment would react to differing levels of emissions of anthropogenic air pollutants. Unsurprisingly, the levels of most emissions fell sharply during the economic lockdown, as many factories shut down and travel decreased. However, the concentrations of one pollutant bucked this trend - tropospheric ozone - which increased sharply following the lockdown.

Many believe that higher ozone levels benefit the environment as it shields the Earth's surface from harmful UV rays. However, the ozone layer responsible for this radiative shielding is in the stratosphere. When ozone builds up closer to the surface (i.e., the troposphere), it is a significant contributor to smog, suffocating plant life and leading to human respiratory illnesses, among other harmful effects. Our current research delves into the causes of increased ozone in India in relation to local meteorological patterns and the relative levels of ozone precursors, such as Nitrogen Oxides and Volatile Organic Compounds. We hope to reference the precursor emission levels in the COVID-19 lockdown conditions to refine understanding of the nonlinear chemical mechanisms behind net tropospheric ozone production. Finally, we plan to quantify the sensitivity of tropospheric ozone production to various forms of anthropogenic emissions in order to better inform future environmental policies.

# EVENTS

## Fall 2020 Seminars Recap

The COVID-19 pandemic forced the Harvard-China Project Research Seminars to use another presentation avenue in the form of Zoom. The virtual format allowed presentations from our Chinese research partners, and the attendance of an audience from across the globe.

The fall semester kicked off with Xi Lu, Associate Professor, School of Environment, Tsinghua University and Harvard-China Project Associate. His talk, "Electrification and Decarbonization: Analysis of Experiences from China, the US and EU" unpacked the distinctive factors affecting electrification and low-carbon power generation in China compared to other countries in recent decades, and the implications for future reductions in energy and carbon intensities.

The second installment was given by Meng Gao, Assistant Professor, Department of Geography, Hong Kong Baptist University and Associate, Harvard-China Project. Professor Gao presented "The Essential Role of Vertical Profile Observations of Atmospheric Composition in China," exploring how the transport and chemistry of air pollutants and their health effects cannot be well understood without measurement of their vertical distributions, beyond conventional observations at the surface and from space.

# RECENT PUBLICATIONS

Haikun Wang, Xiaojing He, Xinyu Liang, Ernani F. Choma, Yifan Liu, Li Shan, Haotian Zheng, Shaojun Zhang, Chris Nielsen, Shuxiao Wang, Ye Wu, and John Evans. 2020. **"Health benefits of on-road transportation pollution control programs in China."** *Proceedings of the National Academy of Sciences*, Sept 2020, 201921271.

Tianguang Lu, Peter Sherman, Xinyu Chen, Shi Chen, Xi Lu, and Michael B. McElroy. 2020. **"India's potential for integrating solar and on- and offshore wind power into its energy system."** *Nature Communications*, 11, 4750.

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Chenghe Guan, Jihoon Song, Michael Keith, Yuki Akiyama, Ryosuke Shibasaki, and Taisei Sato. 2020. **"Delineating urban park catchment areas using mobile phone data: A case study of Tokyo."** *Computers, Environment and Urban Systems*, 81.

Jing Cao, Mun S. Ho, Wenhao Hu, and Dale Jorgenson. 2020. **"Effective labor supply and growth outlook in China."** *China Economic Review*, 61, Pp. 101398.

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Chenghe Guan and Ann Forsyth. 2020. **"The influence of urban form and socio-demographics on active transport: a 40 neighborhoods study in Chengdu, China."** *Journal of Transport and Land Use.*

Mun Ho, Wolfgang Britz, Ruth Delzeit, Florian Leblanc, Roson Roberto, Franziska Schuenemann, and Matthias Weitzel. 2020. **"Modelling consumption and constructing long-term baselines in final demand."** *Journal of Global Economic Analysis*, 5.

Yu Wang, Dasaraden Mauree, Qie Sun, Haiyang Lin, Jean-Louis Scartezzini, and Ronald Wennersten. 2020. **"A review of approaches to low-carbon transition of high-rise residential buildings in China."** *Renewable and Sustainable Energy Reviews*, 131, October 2020, Pp. 109990.

Xi Yang, Jun Pang, Fei Tang, Ruixin Gong, and Cecilia Springer. 2021. **"The environmental co-benefit and economic impact of China's low-carbon pathways: Evidence from linking bottom-up and top-down models ."** *Renewable and Sustainable Energy Reviews*, 136, February 2021, Pp. 110438.