ENVIRONMENT AND NATURAL RESOURCES

Harvard-Tsinghua Workshop on Low-Carbon Development and Public Policy

Report Contributors:

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HARVARD Kennedy School
BELFER CENTER
for Science and International Affairs

RAPPORTEUR'S REPORT
JULY 2018

Environment and Natural Resources Program
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A satellite view of the Gansu Dunhuang Solar Park, a photovoltaic power station under construction in Gansu Provence, as seen on June 9, 2018. (DigitalGlobe, CNES/Airbus, Google Earth, used with permission).

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About

The Environment and Natural Resources Program (ENRP)

The Environment and Natural Resources Program at the Belfer Center for Science and International Affairs is at the center of the Harvard Kennedy School's research and outreach on public policy that affects global environment quality and natural resource management. Its mandate is to conduct policy-relevant research at the regional, national, international, and global level, and through its outreach initiatives to make its products available to decision-makers, scholars, and interested citizens.

More information can be found on ENRP's web site at www.belfercenter.org/enrp or from assistant director, Amanda Sardonis (amanda_sardonis@hks.harvard.edu) at ENRP, Harvard Kennedy School, 79 JFK Street, Cambridge, MA 02138 USA.

The Center for Science, Technology, and Education Policy (CSTEP)

Founded in April 2006, the Center for Science, Technology, and Education Policy (CSTEP) is the hub of research and teaching at Tsinghua University's School of Public Policy and Management. The Center is one of the Soft Science Research Bases authorized by the Ministry of Education (MOE). CSTEP has a dual mission: to serve as an incubator to cultivate future leaders in public policy research and management, and to act as a think tank to provide knowledge-based advice for central and local governments in China on science, technology, and public policy.

Preface

On June 7, 2018, the Harvard Kennedy School's Environment and Natural Resources Program and the Center for Science, Technology, and Education Policy at Tsinghua University held the fifth annual Tsinghua-Harvard Workshop on Low-Carbon Development and Public Policy. This event brought together leading experts on climate and energy from academic, business, and government communities in both the United States and China. Previous workshops dealt with technology innovation, climate, market mechanisms to reduce carbon emissions, and local low-carbon initiatives. This year's workshop focused on electricity systems and renewable energy penetration.

The workshop was divided into three sessions: the first focused on challenges confronting the electricity system in both China and the United States; the second discussed alternative policies to promote and invest in renewable power options; and the last session focused on opportunities and challenges for electric vehicles.

This report is a summary of the major points covered during the workshop. It strives to capture the underlying arguments made by all the participants, including areas in which there was disagreement. In compliance with the rules of discussion as laid out by the organizers, nothing in this report is attributed to a single person. Any errors or misrepresentations are the authors' responsibility.

The authors would like to give special thanks to Professor Su Jun and his team at Tsinghua, who have been instrumental in hosting each of the Harvard-Tsinghua workshops. We deeply appreciate their help in making these events possible.

Financial support for the workshop was provided by the Center for Science, Technology, and Education Policy at Tsinghua University, the Environment and Natural Resources Program at the Belfer Center for Science and International Affairs at the Harvard Kennedy School, and Harvard University's Climate Change Solutions Fund.

Workshop Organizers

Jiankun He, Director and Professor of the Institute of Low Carbon Economy, Tsinghua University; Deputy President, National Expert Committee on Climate Change

John Holdren, Co-Director, Science, Technology, and Public Policy Program; Teresa and John Heinz Professor of Environmental Policy, Harvard Kennedy School

Cui Huang, Associate Professor, Center for Science, Technology, and Education Policy, Tsinghua University

Henry Lee, Director, Environment and Natural Resources Program; Senior Lecturer, Harvard Kennedy School

Daniel Schrag, Co-Director, Science, Technology, and Public Policy Program; Sturgis Hooper Professor of Geology; Professor of Environmental Science and Engineering at Harvard University; and Director of the Harvard University Center for the Environment

Jun Su, Chang Jiang Scholar Distinguished Professor, School of Public Policy and Management, Tsinghua University; Director, Center for Science, Technology, and Education Policy (CSTEP), Tsinghua University

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Cover Image
A satellite view of the Gansu Dunhuang Solar Park, a photovoltaic power station under construction in Gansu Provence, as seen on June 9, 2018. (DigitalGlobe, CNES/Airbus, Google Earth, used with permission)

1. The climate problem and foundations for deep decarbonization

To combat the threat of economic and social disruptions due to climate change, the global community must commit to a long-term goal of deep decarbonization, defined as reducing global greenhouse gas emissions from fossil fuels to zero or even negative. Ambient CO_2 concentrations have been increasing, reaching a monthly mean of 410ppm in 2017 (based on observations at Mauna Loa Observatory). In the past few years, most places in the world have also experienced higher annual average temperatures. In addition, changes in the climate system have already resulted in disruptions, including more severe heat waves, tropical cyclones, droughts, floods, forest fires, and crop damage. Even greater negative impacts are projected in the future. Since CO_2 can remain in the atmosphere for centuries, it is not enough to simply slow down the growth of emissions. In the long run, deep decarbonization will be necessary.

A current challenge is to lay the foundations for deep decarbonization, even if energy technologies (including pricing) are not yet up to the task. Climate change is a long-term problem. Urgent action is necessary, but because of the scale of the problem and the time needed to develop new energy systems, the challenge will persist for many decades. Climate and energy policies, today, should be judged not only by how they relate to immediate goals of emissions reduction, but also by how they contribute to providing options for decarbonization pathways in the future.

China and the United States are in position to promote energy technology innovation and tackle climate change. As the two largest emitters of greenhouse gases, both countries have the opportunity to assume leadership positions. The landmark Xi-Obama climate agreement announced in 2014 outlined a unique collaboration between these two countries. This bilateral agreement also changed the character of global climate governance, which contributed to the success of the Paris Agreement.

China has made substantial efforts to reduce coal consumption and to increase non-fossil energy, and is currently on track to meet its climate pledges. While coal consumption reached 2.81 billion tce in 2013, it fell to 2.71 billion tce in 2017. The annual growth rate of non-fossil energy supply was 11.2% in 2012-2017. During the 13th Five Year Plan period (2016-2020), the annual average GDP growth rate is expected to be around 6.5%, while the growth rate for energy consumption and CO_2 emissions are anticipated to be only 2% and 1%, respectively. By 2020, the CO_2 intensity (the ratio of CO_2 emissions to GDP) is expected to decrease by more than 50% compared to 2005 level. It is therefore very likely that China will peak its carbon emissions before 2030 and achieve the targets pledged in the Paris Agreement to increase the share of non-fossil energy to 20% of primary energy.

In the United States, while the Trump Administration decided to withdraw from the Paris Agreement, efforts have been made by states, cities, business leaders, and universities to continue the support for climate action. The Trump Administration announced its decision to withdraw from the Paris Agreement in 2017, and has initiated a process to reverse many of the climate policies implemented by the Obama Administration, including the Clean Power Plan. These actions have damaged the moral authority of U.S. leadership in tackling climate change, and may result in delayed action and reduced funding for mitigation and adaptation efforts. However, about 70% of Americans believe that climate change is happening, and the percentage is even higher among young people. More than 2,800 leaders from cities, states, universities, and companies have signed the "We are Still In" declaration to stand by the Paris Agreement.

Given the present-day situation, two lines of cooperation between Chinese and U.S. scholars are especially valuable. The first is to work with each other to promote climate action from all entities, rather than be limited to government negotiations. The bottom-up action from states, cities, counties, universities, businesses, and investors provides opportunities for new forms of partnership between a wide range of actors to pursue ambitious climate goals. Second, organizations in both countries can partner with each other to flesh out and evaluate policies for innovation, mitigation, and adaptation, so that when the opportunities present themselves, actions can be taken.

2. **Renewable integration**

In both China and the United States, wind and solar are no longer "alternative energy." Renewable energy has the potential to become central to the strategy for achieving long-term decarbonization. Costs for wind turbines and solar PV are declining rapidly. Both countries have introduced policies to promote renewable energy growth. China has introduced renewable feed-in-tariffs as well as installation targets. China's national cap-and-trade system, announced in December 2017, will introduce a price on carbon for the electric utility sector, which is one of China's largest carbon sources. The United States has employed a blend of policy mechanisms, such as tax credits, direct subsidies, and renewable energy mandates. Transformative changes are also happening in the U.S. power sector with respect to decarbonization, digitization, and decentralization. As a result, installations of wind and solar have grown substantially in both countries. Both countries anticipate continued growth in renewables capacity in the coming decades. China pledged to increase the share of non-fossil energy in its total primary energy to 20% by 2030. While in the United States, many states announced ambitious renewable or clean energy requirements (e.g. renewable portfolio standards), such as California (50% by 2030), New York (50% 2030), Hawaii (100% by 2045), and Massachusetts (45% by 2050).

However, integrating intermittent renewable electricity poses technical challenges to the electricity system. In the traditional power system, the variations in load are balanced by dispatching thermal units and hydropower. Meanwhile, given the intermittent nature of wind and solar generation, high penetration of renewables creates challenges for real-time electricity balancing. The variations in net demand (i.e. total demand subtracted by the power from intermittent wind and solar resources) need to be met by the remaining capacity in the generation fleet. It requires faster ramp rates and lower system inertia, as well as more frequent cycling of the non-renewable capacity. During the hours when wind and solar resources are high, the net demand may also become negative, leading to the need for curtailment of both thermal and renewable capacity.

China and the United States both face common and different challenges. Both countries face a geographic mismatch between regions with abundant resource capacity and regions with the highest demand. Constructing additional long-distance electricity transmission is, therefore, an option to move large amount of renewable electricity to load centers. However, China's electricity system is dominated by coal-fired power plants, while the United States is in the midst of a natural gas "revolution," leading to more gas-fired power plants and lower CO_2 emissions. Compared to gas-fired power plants, coal-fired power plants have a slower ramp rate and therefore are less able to accommodate variable output from renewables. The coal-dominated electricity system and a lack of natural gas resources lead to unique system challenges in China. In fact, in recent years renewable curtailment rates have been high in China, especially in northern regions, due in part to the inflexibility caused by the "equal share" dispatch rule, as well as inadequate transmission investments.

Building a portfolio of technical solutions may be beneficial for renewable integration. To accommodate high penetration levels of renewables, technical improvements in both generation and transmission systems will be critical. First, the generation system needs to be more flexible, e.g. greater ramping capability and lower cycling costs. It is important to have capacity that is suited for low or high utilization and can be operated in a flexible way. Second, a more integrated transmission system can expand the balancing area for renewables and smooth out the variability in loads. For instance, China has made substantial efforts to plan and build a large electricity grid, connected by ultra-high-voltage transmission lines (both AC and DC). Such an expansion in transmission capacity could be beneficial for renewable transmission and integration. Other technical strategies proposed by workshop participants include renewable integration in China such as cross-region wind and solar balancing, providing flexibility through cloud energy storage, multiple energy system integration, concentrated solar power with heat storage, improving the coordination between wind farms and CCS, as well as big data and artificial intelligence to improve weather forecasting.

3. Electricity sector practices and reforms

In recent years, China has introduced a series of guidelines to facilitate market-oriented electricity reform, some of which may benefit renewable integration. For instance, a major government document on power market reform was released in 2015 (NO.9 Document). It introduced guidelines to improve electricity trading across provinces, improve compensation schemes for ancillary services, establish a cost-sharing mechanism between generators and end users, and encourage the development of distributed energy markets. Although the details of the market reform are still evolving, the broad direction of these reforms is to create price signals that will improve the dispatch of renewable electricity and compensate the generation units that are used to balance the load during times when renewable generation is not adequate.

In the United States, market-oriented solutions provide opportunities to reach higher renewable penetration levels. Market solutions being discussed in the United States include efficient spot markets, co-optimization of day-ahead energy and spinning reserve markets, and improved forward markets. Efficient spot markets require least-cost dispatch with spot prices based on actual marginal cost. Increasing the time increments (e.g. 5 minutes) of the spot markets could also reward flexibility. In addition, co-optimizing reserve requirements and energy spot market could make the operations of the power sector more efficient. Finally, forward markets provide market participants hedging opportunities against short-term uncertainties in electricity prices. Deepening the markets for forward contracts is thus beneficial for managing the risks in a high-renewable system.

However, important gaps between the market reform efforts proposed by the Chinese government and those currently operating in the United States remain. For instance, electricity prices in China are largely set by the government. Given the "equal share dispatch" (i.e. allocating roughly the same annual operating hours for thermal generation units in the same technological class), the electricity rates in China do not reflect the marginal cost of production. In comparison, the wholesale electricity markets in the United States already include day-ahead and real-time markets where the price is essentially determined by the cost of generating the last unit of electricity to meet demand. The market solutions proposed by some participants in the workshop are practices that are also currently not implemented in the United States, but can further create market signals to facilitate higher levels of renewable penetration, such as co-optimization of reserves and spot markets as discussed in the previous section. It is also worth noting that there is a significant efficiency gap between current practices and ideal operation in China's power sector. In sum, the proposed electricity reforms in China are moving in the direction of a more market-oriented system, but are still far away from relying primarily on market solutions. A likely outcome in the near term is a grid system in China that continues to rely primarily on central planning and state-owned enterprises supplemented by market mechanisms—where such mechanisms are clearly beneficial.

In the long term, achieving a zero-carbon power system will require different sets of technical and market solutions. Full decarbonization of electricity generation means that countries can no longer rely on natural gas or coal without carbon capture and sequestration. There are also economic limits to variable renewable energy, because the costs and technical challenge rise non-linearly once renewable penetration levels reach 80%. In a zero-carbon power system, firm zero-carbon resources will become necessary; potential candidates include nuclear, reservoir hydro, and biomass. Therefore, systems dominated by zero marginal cost and variable resources will face enhanced market design challenges and require new solutions.

4. Electrification of vehicle fleet and China's policies

The automotive industry is undergoing a profound revolution, including greening, electrification, intellectualization, and interconnection and sharing. Greening has become a key criterion for future vehicle development. Electrification is considered an effective technology route for future environmentally-friendly vehicles. Some countries, such as Norway, Netherlands, England, France, and Scotland, have announced future prohibitions on the sales of fossil fueled vehicles. Many enterprises in Europe, the United States, Japan, and China also have set forth a timeline for vehicle electrification. In addition, helped by new battery technologies, the price of lithium-ion (Li-ion) power batteries has fallen in the five-year period, ending in 2016. Many experts expect the net present value (NPV) of an electric vehicle (EV) over its lifetime will be equal to the NPV for fossil fuel-powered vehicles sometime between 2025 and 2030. However, many challenges remain.

EV sales are increasing rapidly, but no one knows whether this growth will continue. Several participants from China provided an overview of EV sales in the past few years. The global EV market share has increased from 0.32% of all automobiles sold in 2014 to 1.35% in 2017. The Chinese market is growing even faster, from 0.38% in 2014 to 2.61% in 2017. The exact sales of EVs in 2017 are about 1.22 million globally and 0.78 million in China, indicating that China is the biggest EV market in the world. In order to support the EV industry, China is developing new charging facilities and improved Li-ion power batteries. Major countries in the world have built more than 445,000 charging facilities, half of which are in China.

Besides EV sales, the electrification of buses and taxis has also increased. In 2014, the Ministry of Transport predicted that 200,000 new energy vehicles would be on the road (10,000 buses, 50,000 taxis, and 50,000 delivery cars) in 2020. The target was achieved in 2017 and was increased to 600,000 EVs for 2020. All the 16,359 buses are now 100% electric in the cities of Shenzhen and Guangzhou, and 8,292 taxis are 100% electric in Taiyuan. At the same time, EV application in the logistics industry increased. International companies like UPS, FedEx, and DHL have begun to purchase fuel cell vehicles, while domestic companies like JD Logistics, China Post, and SF Express have made plans for using BEVs.

When it comes to the policies, traffic and purchase restrictions can provide a powerful encouragement for purchasing and operating an EV, especially in larger cities like Beijing and Shanghai. According to several surveys, license plate allocations have the biggest impact on EV sales. For example, Beijing sales increased dramatically after the no traffic restriction policy was removed for EVs, which meant that the owner of an EV did not need to enter the license plate lottery and could ignore the even- and odd-numbered license plates restrictions. Under China's Corporate Average Fuel Consumption (CAFC) regulations, New Energy Vehicle (NEV) sales can be credited to vehicle manufacturers or traded to firms that are not able to meet these stringent standards.

In the future, China will focus on four key challenges. First, electricity markets and tariffs may restrict consumer confidence in BEVs, including volatility, availability, costs, and emission factors. For example, how EVs will be charged, what will be the cost of power, and how much of the power will come from renewable energy sources remains uncertain. The answers to these questions will significantly influence the cost and environmental impacts of EVs. Second, the technology is still evolving. Which type of vehicle will be the highest priority for vehicle manufacturers and the government? Pure EV, hybrid EV, plug-in hybrid EV, or hydrogen energy vehicle? Third, China does not yet have a dominant position in many of the industries in the BEV supply chain, such as batteries and electric motors, which handicaps Chinese aspirations for global leadership in EV production. China has many vehicle-manufacturing companies and a significant number of them are planning to build EVs. There is a danger that China will have an overcapacity problem, which will depress EV prices for a short period. Fourth, what new programs and policies will be developed and implemented at both the provincial and national levels in the next decade?

5. Cost-effectiveness of EVs in the United States

In the United States, the cost-effectiveness of EVs remains uncertain. Will EVs be cost competitive with Internal Combustion Engine Vehicles (ICEVs)? The answer depends on assumptions about fuel prices, discount rates, battery costs, and annual miles driven. Two questions remain to be answered: What is the price of EVs over their lifetime compared with the price of ICEVs over their lifetime? What is the cost of charging an EV as compared with fueling an ICEV and how much less convenient will it be to charge an EV as opposed to fueling a gasoline-powered vehicle?

The key cost component for an EV is the battery, and it remains high. One of the presenters claimed that in the United States, the installed battery cost are between $318 and $400 per kWh. This cost is decreasing as the technology improves, but EV manufacturers in the United States and European Union are expanding the battery capacity to reduce consumer range anxiety. Therefore, the net costs of battery packs in EVs remain high. A recent Harvard study assumed a gasoline price of $2.50, an electricity price of $0.17 per kWh, an average consumption of 0.37 kWh per mile and an annual mileage per vehicle of 13,476 miles. Considering the discount factor of 15%, the NPV over 10 years of an EV's life will be equal to that for an ICEV, if the battery cost reaches approximately $225 per kWh. However, despite their high cost, vehicle manufacturers in the United States are forced to produce a certain percentage of EVs in order to meet the regulatory mandates in certain states, primarily California.

Charging costs are also important. EV charging in the United States can be classified into five levels: levels 1-2 are residential charging and levels 3-5 are fast charging. How electricity tariffs are designed will have a large impact on the economic viability of home charging. If the local utility charges time-of-use rates and the owner owns a smart meter, the cost could drop significantly. Public level 2-4 charging (on commercial tariffs) is more expensive than residential charging, because the equipment is larger and the installation costs are higher. In the United States, some government-subsidized chargers may be inadequate to charge the larger batteries in newer cars.

*Demand charges are calculated based on the highest demand recorded during a month***.** In the United States, commercial fast-charging operations, as opposed to residential chargers, must pay these costs, thus putting pressure on fast-charging stations to generate substantial revenues to cover these expenses. Level 3-5 fast charging would be subject to both a demand charge and a variable or energy charge. Utilization rates become extremely important to increase profitability. If the utilization rate can reach 40%, the cost of an EV using level 4 and level 5 fast charging can be almost equal to a 40 mpg ICEV, and less than a 24 mpg ICEV.

EVs have the potential to become cost-effective over the next decade, but challenges remain. First, the charging time will influence the consumers' preference. Fueling an ICEV takes 5 minutes with very few safety concerns, but charging an EV will take longer and be less convenient. Second, rapid deployment of EVs will put pressure on regulators to design tariffs that more closely resemble real time costs.

Conclusion

*Many important scientific and political topics have been analyzed and discussed at the Tsinghua-Harvard workshops***.** Researchers have shown that a low-carbon economy is at the core of tackling climate change in the framework of sustainable development. Therefore, the reform of electricity markets and the penetration of renewable energy are extremely important, especially when EVs are gradually taking the place of ICEVs.

The electricity transition and the application of renewable energy in China aims to move China and the United States to a lower carbon economy. Both countries will need to gradually improve the penetration of renewable energy and establish a more open market system. However, many challenges remain. As the penetration rate of renewable energy becomes higher, issues such as the lack of grid flexibility and the separation of generating sources and loads will become more problematic, and could result in greater curtailment of wind and solar power. The integration of renewable energy presents great uncertainties to the power systems, requiring faster ramp rates, and more frequent cycling. Greater reliance on intermittent sources will require a more intense focus on flexibility. In China, the inverse distribution of renewable energy sources and power load is an important issue. Most of the renewable energy sites are in the northwest, but the large load centers are in the southeast, so long-distance power transmission is necessary. For example, China is now planning and constructing a huge ultra-high voltage power grid to address the inverse distribution problem. At the same time, competitive energy storage technology may emerge and become an effective way to compensate for the fluctuations in generations, but this technology is still in development.

The emergence of electric vehicles is also an important topic since over time it could significantly influence carbon emissions from the transportation sector, especially under a renewable intensive scenario. China is the world's largest EV market, and this market is likely to keep growing. The next step for China is to solve the problems related to the challenges in five key areas – electricity reliability, technology innovation, the development of a domestic supply chain, too many car manufacturers, and environmental sustainability.

The Tsinghua-Harvard workshop remains an important platform for experts from China and the United States to discuss scientific and political problems on energy and environment, such as low carbon development, electricity sector reform, and EV penetration. This track 2 dialogue can help experts learn from each other and learn more about the policies or technologies in each country. Although each system has its limitations, solutions will become clearer through discussions between U.S. and Chinese experts.

Appendix B: Participants

John Holdren, Teresa and John Heinz Professor of Environmental Policy at the Kennedy School of Government; Co-Director of the Center on Science, Technology, and Public Policy in the Kennedy School's Belfer Center for Science and International Affairs

Appendix A: Agenda

June 6th				
15:00-16:30	**Open Panel: Climate Change: Global Challenges and Cooperation**			4th Floor Lecture Hall, Tsinghua University Art Museum
	Speaker	John Holdren	Professor, Director of Environment and Natural Resources Program, Harvard Kennedy School	
	Respondent	Lan Xue	Professor, Dean of School of Public Policy and Management, Tsinghua University	
	Speaker	Jun Su	Professor, School of Public Policy and Management, Tsinghua University	

June 7th				
09:00-09:10	**Opening Remarks**			4th Floor Lecture Hall, Tsinghua University Art Museum
	Jun Su		Professor, School of Public Policy and Management, Tsinghua University	
	Henry Lee		Professor, Director of Environment and Natural Resources Program, Harvard Kennedy School	
09:10-10:10	**Keynote Speech**			4th Floor Lecture Hall, Tsinghua University Art Museum
	Moderator	Henry Lee	Professor, Director of Environment and Natural Resources Program, Harvard Kennedy School	
	Speaker	John Holdren	Professor, Director of Science, Technology and Public Policy Program, Harvard Kennedy School	
		Ganjie Li	Minister, Ministry of Ecology and Environment of the People's Republic of China	
		Jiankun He	Professor, Dean of Institute of Low Carbon Economy, Vice Executive President of Tsinghua University	
10:10-10:20	Group Photo & Coffee Break			
10:20-12:00	**Session 1: Electric Power System Reform and Penetration of Renewable Energies**			4th Floor Lecture Hall, Tsinghua University Art Museum
	Moderator	Daniel Schrag	Professor, Director of Science, Technology and Public Policy Program, Harvard Kennedy School	
	Speaker	Yaowei Sun	Inspector of the Law and Reform Department of the National Energy Administration	
		Jesse Jenkins	Researcher, Massachusetts Institute of Technology, MIT	
	Respondent	Cong Cao	Professor, School of Business, University of Nottingham	
		Jingdong Xie	Professor, Shanghai University of Electric Power	
		Zheng Liang	Associate Professor, School of Public Policy and Management , Tsinghua University	
	Free Discussion			

12:00-13:30	Lunch			Wenjin Hotel
14:00-15:30	**Session 2: Technology and Policy to Promote Renewable Energy Penetration**			4th Floor Lecture Hall, Tsinghua University Art Museum
	Moderator	Ye Qi	Professor, School of Public Policy and Management, Tsinghua University	
	Speaker	Chongqing Kang	Professor, Deputy Director of the Low-carbon Energy Research Institute at Tsinghua University	
		Daniel Schrag	Professor, Director of Science, Technology and Public Policy Program, Harvard Kennedy School	
	Respondent	Qiang Yao	Professor, Department of Thermal Engineering at Tsinghua University	
		Jianqiang Cao	Director, Jiaxing Environmental Protection Bureau	
		Ciqi Mei	Associate Professor, Vice Director of Government Research Institute, School of Public Policy and Management at Tsinghua University	
15:30-15:40	Coffee Break			
15:40-17:30	**Session 3: Technology and Market of Electric Vehicles Development**			4th Floor Lecture Hall, Tsinghua University Art Museum
	Moderator	Xiliang Zhang	Professor, Management Science & Engineering and Director of the Institute for Energy, Environment & Economy, Tsinghua University	
	Speaker	Yongwei Zhang	The Secretary-General and Chief Expert of the China EV100	
		Henry Lee	Professor, Director of Environment and Natural Resources Program, Harvard Kennedy School	
	Respondent	Changming Xu	Vice director, State Information Center	
		Zijian Zhen	Deputy chief of the department of transportation, Ministry of Science and Technology	
		Junming Zhu	Assistant professor, School of Public Policy and Management at Tsinghua University	
	Free Discussion			
17:30-18:00	**Closing Session**			4th Floor Lecture Hall, Tsinghua University Art Museum
	Daniel Schrag		Professor, Director of Science, Technology and Public Policy Program, Harvard Kennedy School	
	Henry Lee		Professor, Director of Environment and Natural Resources Program, Harvard Kennedy School	
	Jiankun He		Professor, Dean of Institute of Low Carbon Economy, Vice Executive President of Tsinghua University	
	Jun Su		Professor, School of Public Policy and Management, Tsinghua University	
18:00-19:00	Dinner			Wenjin Hotel

Daniel Schrag, The Sturgis Hooper Professor of Geology, Professor of Environmental Science and Engineering at Harvard University; Co-Director of the Science, Technology, and Public Policy Center at the Belfer Center for Science and International Affairs at the Harvard Kennedy School

Henry Lee, Director of the Environment and Natural Resources Program within the Belfer Center for Science and International Affairs at Harvard Kennedy School; Faculty Co-Chair of the Center's Energy Technology Innovation Policy project; and a Senior Lecturer in Public Policy

Jiankun He, Professor and Dean of the Institute of Low Carbon Economy at Tsinghua University; Vise Director of the National Expert Committee for Climate Change

Jun Su, Cheung Kong Scholar Chair Professor in the School of Public Policy and Management at Tsinghua University; Director of the Center for Science, Technology and Education Policy (CSTEP) at Tsinghua University; and Deputy Director of the Advisory Committee of the Public Administration under the Ministry of Education

Cui Huang, Associate Professor and Vice Director of the Institute of Political and Public Policy and Vice Director of the Center for Science, Technology & Education Policy (CSTEP) at the School of Public Policy and Management at Tsinghua University

Jesse Jenkins, MS in Technology & Policy and PhD candidate in Engineering Systems at the Institute for Data, Systems and Society at the Massachusetts Institute of Technology; researcher with the MIT Energy Initiative

Cong Cao, Professor in innovation studies at the Faculty of Business at the University of Nottingham; member of the Global Futures Council since 2016

Gloria Zhou, Director of Strategy and Business Portfolio, BP (China) Investment Holding Ltd.

Min Hu, Executive Director for Innovative Green Growth Program (iGDP); China Advisor and Program Head of Access to Cooling at Kigali Cooling Efficiency Program; Non-Resident Senior Fellow at Tsinghua Brookings Center; and Senior Fellow al Energy Innovation

Wei Peng, Giorgio Ruffolo Postdoctoral Research Fellow in Sustainability Science, Environment and Natural Resources Program, Harvard Kennedy School

Pu Wang, Associate Professor at Institutes of Sciences and Development at the Chinese Academy of Sciences researching China's emissions trading program; former postdoctoral fellow at the Belfer Center for Science and International Affairs at the Harvard Kennedy School

Qinyu Qiao, Predoctoral Fellow with the Environment and Natural Resources Program at the Belfer Center for Science and International Affairs; Ph.D. candidate at the Automotive Strategy Research Institute at Tsinghua University researching energy and environment issues related to new energy vehicles

Rongtao Sun, Director of Technology Innovation and Investment, BP China

Zhu Liu, Thousand Talent Associate Professorship at Earth System Science at Tsinghua University; lecturer at Tyndall Centre for Climate Change Research at UEA; and Associate at the Belfer Center for Science and International Affairs at Harvard Kennedy School.

Wenjia Cai, Associate Professor of Global Change Economics, Department of Earth System Science at Tsinghua University; member of the Energy System Engineering Specialized Committee, China Energy Research Society; and Vice Director of Tsinghua-Rio Tinto Research Center for Resources, Energy and Sustainable Development

Qixin Chen, Associate Professor of the Department of Electrical Engineering and Vice Director of the Energy Internet Research Institute at Tsinghua University; Vice Director of TsinghuaSichuan Energy Internet Research Institute

Maosheng Duan, Professor at the Institute of Nuclear and New Energy Technology and Director of China Carbon Market Center (CCMC) of Tsinghua University; member of the Chinese delegation to the United Nations climate negotiations since 200I

Jie Hao, Lecturer at the School of Economics and Management, Tsinghua University, in the Department of Innovation, Entrepreneurship and Strategy

Chongqing Kang, Professor and Chairman of the Executive Committee of the Department of Electrical Engineering at Tsinghua University; Deputy Director of the Low-carbon Energy Research Institute of Tsinghua University

Zheng Li, Cheung Kong Scholar Chair Professor, Dean of the Department of Thermal Engineering at Tsinghua University; Founder and Director of the Tsinghua BP Clean Energy Research and Education Center

Zheng Liang, Associate Professor of the School of Public Policy and Management and Deputy Director of China Institute for Science & Technology Policy (CISTP) at Tsinghua University

Ciqi Mei, Associate Professor and the Vice Director of Government Research Institute, School of Public Policy and Management at Tsinghua University

Xumming Ou, Associate Professor of Institute of Energy, Environment and Economy, Tsinghua University; one of the Subject Editors of Energy Journal, Lead Authors of IPCC AR6; Deputy Director of the China Automotive Energy Research Center of Tsinghua University; Deputy Sectary General of Energy System, Engineering Committee of China Energy Research Society

Ye Qi, Cheung Kong Scholar Chair Professor; Professor of the School of Public Policy and Management at Tsinghua University; Director of Brookings-Tsinghua Center for Public Policy

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