ENVIRONMENT AND NATURAL RESOURCES

# Foundations of Decarbonization in China

## A post-2030 perspective

Henry Lee

Wei Peng

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HARVARD Kennedy School
BELFER CENTER
for Science and International Affairs

WORKSHOP REPORT
JULY 2017

**Environment and Natural Resources Program**
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Design & Layout by Andrew Facini

Cover photo: Steam and white smoke is emitted on Feb. 28, 2017 from China Huaneng Group's Beijing power plant—the last coal-fired plant to shut down on March 18, 2017 as the Chinese capital converts to cleaner energy sources. (AP Photo/Andy Wong)


Printed in the United States of America

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# About 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.

# About 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

The Harvard-Tsinghua Workshop on Low-Carbon Development and Public Policy is the fourth annual joint workshop between the Harvard Kennedy School's Environment and Natural Resources Program and the Center for Science, Technology, and Education Policy at Tsinghua University. The workshop convened leading experts on climate and energy from the United States and China at Tsinghua University in Beijing, China, on June 1-2, 2017.

The first half of the workshop, titled "Foundations of Decarbonization in China: A Post-2030 Perspective," was divided into five sessions. The first two sessions focused on the scope of the climate problem and the options for addressing it. The following three sessions explored specific options: renewable energy, nuclear power, and air pollution regulation. The second half of the workshop focused on "Opportunities for Cooperation on Regulating Nuclear Safety and Security." A separate workshop report published by the Project on Managing the Atom will focus on the nuclear regulation sessions.

The discussion sessions followed Chatham House Rule: nothing discussed can be attributed to individuals or organizations. The report represents a synthesis of the main points and arguments that emerged from the discussion. It is not a consensus document, since no effort was made to arrive at a single view. Rather, the report reviews the major themes discussed and where there was significant disagreement, we attempted to present both sides of the argument. Any errors or misrepresentations are the authors' responsibility.

Financial support for the workshop was provided by the Center for Science, Technology, and Education Policy at Tsinghua University, the Sustainability Science Program, the Project on Managing the Atom, and the Hui Fund for Generating Powerful Ideas at the Ash Center for Democratic Governance and Innovation at the Harvard Kennedy School.

## Workshop Organizers:

**Matthew Bunn**, Principal Investigator, Project on Managing the Atom; Professor of Practice at Harvard Kennedy School

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

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

**Daniel Schrag**, 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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A passenger airliner flies past steam and white smoke emitted from China Huaneng Group's Beijing power plant on Feb. 28, 2017. This facility was the last coal-fired plant to shut down on March 18, 2017 as the Chinese capital converts to cleaner energy sources. (AP Photo/Andy Wong)

# 1. Why the climate problem is important

Stabilizing the climate system requires substantial reduction in greenhouse gas (GHG) emissions, mainly through changes in energy systems that are currently dominated by fossil fuels. In the Paris Agreement, countries pledged to take voluntary carbon mitigation actions over the next 10-15 years. The climate system responds to cumulative GHG emissions, and carbon dioxide ($CO_2$) can remain in the atmosphere for several centuries. Therefore, stabilizing $CO_2$ emissions is not sufficient. The goal must be one of deep decarbonization, reducing global $CO_2$ emissions to zero by the end of this century.

As the first and second largest $CO_2$ emitters in the world, both China and the United States face critical challenges in the design, development, and implementation of deep decarbonization. China has pledged to peak its carbon emissions by 2030, and to increase the share of non-fossil energy in total primary energy to 20%. The United States pledged to reduce its carbon emissions by 26-28% below 2005 levels by 2025, a goal that is now being questioned as a result of President Trump's recent decision to withdraw from the Paris Agreement. While these targets promise near- and mid-term steps to mitigate carbon emissions, much stronger efforts will be needed after 2030 to eventually achieve zero or negative emissions. Therefore, the path towards deep decarbonization will likely involve multiple stages, and the policy priorities will vary with each stage. For instance, the first stage, pre-2030, will focus on increasing wind and solar generation, and replacing coal with natural gas. The second stage, from 2030-2050, may focus on a continuing expansion of renewables, deployment of storage technologies, as well as electrification of the transport, heating, and industrial sectors. The third stage, post-2050, may focus on deploying CCS for natural gas use, biofuels and synthetic fuels, as well as advanced nuclear technologies.

Compared to the United States, the fundamental challenge faced by China is its heavy reliance on coal. Analyses on potential

decarbonization pathways for China highlight two findings. First, reducing carbon emissions beyond stabilization will be difficult. Multiple factors have contributed to reductions in the use of coal, including economic slowdown and the urgency to curb conventional air pollution. Under various assumptions on GDP growth projections, urbanization rates, and reductions in carbon intensity, the CO2 emissions peak is anticipated before 2030. However, the share of emissions from the electricity sector as a percentage of China's total emissions is expected to continue to grow beyond 2030. A few key variables that will affect such a change after 2030 include the speed of renewable and nuclear scale-up, the level of efficiency improvement of incumbent coal power fleet, and the development of natural gas plants to meet demand when renewable energy is interrupted. In summary, it is widely acknowledged that achieving an energy mix that is 60-80% decarbonized (necessary for deep reduction in carbon emissions) is a much more difficult task than the near-term target of 20-25% (necessary for peaking carbon emissions).

Second, deep decarbonization scenarios for China's energy system often depend on significantly scaling up renewable and nuclear generation in the electricity sector, as well as electrification efforts in the end-use sectors. Although these scenarios are carefully designed based on a deep understanding of China's current energy system and projected growth, they still contain uncertainties. How to manage the intermittency problems for renewables and address safety concerns for nuclear energy are important challenges in almost every decarbonization scenario.

In this report, we start with a summary of the three key topics: electricity sector reform, synergies between climate and air pollution control efforts, and nuclear power development. We then focus on four cross-cutting themes that are relevant for all three topics: (a) implications of current policies on long-term decarbonization, (b) challenges in energy and climate governance, (c) public participation and engagement, and (d) decarbonization and the pursuit of other societal goals. Finally, we draw some preliminary conclusions and discuss potential directions for future scenarios.

# 2. Brief summaries of the session topics

## a. Electricity market reform

What are the implications of China's electric power system to long-term decarbonization? Two issues emerged: (a) infrastructure planning for renewable energy expansion, and (b) reforming electricity dispatching and pricing policies. As several participants pointed out, the problems regarding renewable energy integration are universal, and the experiences from other countries can shed light on China's policy making, and vice versa. But some of China's challenges in reforming its electricity markets are unique, due to historical and sociopolitical factors. Addressing those challenges will require a deeper understanding of China's specific challenges.

In the past decade, China has made impressive progress in clean energy development and has become the world's leader in both manufacturing and deployment of wind and solar generation. Part of these accomplishments are attributable to policy and financial incentives, such as feed-in tariffs for wind and solar, and subsidies from China's Renewable Energy Development Fund, which was initiated jointly by the Ministry of Finance, National Development and Reform Commission (NDRC), and National Energy Administration. Nevertheless, China faces challenges in integrating the fast-growing wind and solar capacities into the power system. High curtailment rates are pervasive especially in those provinces that are rich in wind and solar resources.

How to address this issue? One option is to construct long-distance and high-voltage transmission lines to connect the consumption centers with resource-rich regions. A key policy challenge to this approach is how to share the costs for the needed infrastructure construction and grid system upgrades, which are very expensive. Additional costs to renewable energy integration include the development of backup units and storage facilities. Two participants pointed out that it is important to recognize that the full costs of renewable energy development are greater than the construction

costs of wind and solar farms alone. A second option is to build distributed wind and solar plants close to consumption centers, which in many cases have sub-optimal wind and solar endowments. This approach will reduce the pressure on the national grids, as well as the costs in infrastructure construction, but may result in a less efficient system and higher wholesale costs of power. Several participants drew parallels between China and the United States, which faces a similar set of problems. In the United States, wind and solar resources are located in the central part of the country, but consumption centers are on the two coasts.

Many participants highlighted the fact that China's electricity system has evolved from a centrally planned and vertically integrated state monopoly, and the market-based and central planning features are deeply intertwined with each other. These peculiarities have set barriers to low carbon energy development. For example, the "equal share" dispatch policy gives fixed generation quotas to different types of generators, and prevents full utilization of low-carbon energy sources. The on-grid and retail electricity prices are set by government regulators and do not necessarily reflect the actual fluctuations in demand and supply and thus, do not send market signals to encourage the development of low-carbon technologies. "Cross subsidies," the subsidization of residential electricity prices by industrial and commercial users, also distort the market. Several participants argued that critical reforms are needed in both system operation and pricing. They could include: (a) creating system operating agencies independent of the generation and distribution companies; (b) establishing market-oriented pricing mechanisms that encourage competition for both power generation and retailing; and (c) coordinating electricity policies with low-carbon policies, such as carbon markets and renewable energy portfolio standards, to enhance integration of renewable energy sources. There was no unanimity around the viability of such reforms, and participants understood the difficulties in garnering support for them, due to the complexity of the power system and the strong interest groups that are against certain reforms.

## b. Synergies between climate and air pollution control efforts

Curbing air pollution and associated health risks has become a top priority for the Chinese government. Since the announcement of the Action Plan on Air Pollution Control in 2013, the annual average PM2.5 concentrations in three major eastern metropolitan areas (Beijing-Tianjin-Hebei, Yangtze River Delta region, and Pearl River Delta region) have been decreasing steadily. Such an improvement is largely owed to strengthened conventional air pollution control measures, including an emphasis on adjusting energy structures to reduce the reliance on coal. However, the efforts to improve air quality demonstrate significant regional variations: while the Pearl River Delta region may need only five years to comply with the national standard of 35ug/m3 for the annual mean PM2.5 concentrations, the Beijing-Tianjin-Hebei region and Yangtze River Delta region will likely need 10 and 15 years respectively to improve from their current emission and pollution levels to meet the target of 35ug/m3.

China's efforts to clean up its air in the near term will affect carbon emissions in the long term. There are two main linkages. First, many energy-related activities contribute to both air pollution and carbon emissions. Some measures to reduce air pollution can therefore bring carbon mitigation co-benefits, while others may bring dis-benefits. Co-benefits include reducing coal use and improving energy efficiency. Air pollution abatement measures that may result in carbon dis-benefits include the production of synthetic natural gas from coal that reduces conventional air pollution, but increases life-cycle carbon emissions. Second, based on atmospheric sciences, air pollutants are associated with positive or negative radiative forcing, which in turn affects global warming. Due to the efforts to address air pollution, the reduction in cooling aerosols, such as sulfate, nitrate, and organic carbon improve air quality, but actually lead to more warming by allowing more direct sunlight.

There are additional challenges to harness climate co-benefits from air pollution control measures. First, the definition of co-benefits (and dis-benefits) warrants closer scrutiny. For instance, the impacts of air pollution and carbon policies on macroeconomic conditions, such as

employment and GDP, is clearly important, but not included in the calculations of co-benefits. Other sustainability issues, such as water scarcity and pollution should also be included in evaluating the overall societal implications of government policies. Second, the governance structures for conventional air pollution abatement and the reduction of carbon emissions remain disconnected. Air pollution control is under Ministry of Environmental Protection and climate change is the responsibility of the National Development and Reform Commission. Coordination between these agencies is important to maximize these co-benefits. Third, transitioning towards an energy structure with a lower dependence on coal will open more opportunities for co-benefits. However, it is difficult not only to identify optimal energy transition pathways for China, but also to manage such a transition given existing interests groups. For example, the adoption of electric vehicles may result in increased air pollution and $CO_2$ emissions in the near-term due to coal power generation, but could contribute to long-term decarbonization as non-fossil fuel generation replaces coal. To understand the role of electrifying the personal vehicle fleet in China's overall decarbonization strategy requires a bridge between near term and long term perspectives.

## C. The role of nuclear power in decarbonization

Deep decarbonization in the long run is likely to require a portfolio of energy strategies. One of the most promising is nuclear power. The participants engaged in in-depth discussions around the status, prospects, and challenges of China's nuclear power development. China's current nuclear power fleet consists of 32 operating units, equal to 30 GW of generating capacity. All the operating units are located on coastal sites. Their performances are above the industry average based on the indicators of World Association of Nuclear Operators (WANO). China's target for 2020 is to have 58 GW of generating capacity in operation, and another 30 GW under construction. Given the low ebb of nuclear power in most other major countries, China's nuclear plan is the most ambitious in the world.

But as many participants pointed out, the current pace of development is insufficient for nuclear to play a major role in China's climate mitigation. Even a high nuclear growth scenario, based on current projections, would only fill a relatively small gap in carbon emissions reductions by 2050. Indeed, Terawatts, rather than dozens of GWs, of generating capacity will be needed globally to make a meaningful impact on emissions reduction, but that scale of development is hard to imagine without major changes in technology and public acceptance. One of the key insights from the discussion was that it is still necessary to invest in research, development, and deployment of advanced technologies, in order to keep the option to scale up nuclear generation in the future. China should explore alternative R&D portfolios, develop lower-cost financing, and improve regulations (without sacrificing safety and security).

Scaling up nuclear power will face substantial constraints and risks. Four of the major challenges were discussed in depth. First, siting of nuclear plants is often controversial, due to public opposition, water availability, and the preferences of local governments and companies. Second, the costs of nuclear plant construction are usually higher per unit of capacity and more unpredictable compared to other energy sources, making nuclear less attractive to investors. Some participants, however, pointed out that state-owned enterprises may find it easier to manage the financial risks surrounding nuclear power, as in the case of China, than for private investors, as in the cases of western countries. Third, safety (safe operation) and security (terrorists, proliferation, etc.) risks, both real and perceived, are significant barriers to nuclear development. And finally, the government and industry capacities, in terms of people, institutions, and expertise, may be unable to keep up with an aggressive nuclear scenario.

# 3. Four cross-cutting themes

## a. Implications of current policies on long-term decarbonization

Efforts have been made to develop possible energy and emission pathways for China to achieve deep decarbonization. While these efforts help us visualize possible pathways going forward and understand the critical challenges ahead, choosing optimal decarbonization pathways in advance is very difficult. Therefore, one of the themes of this workshop was to examine near-term policy decisions through the lens of their long-term implications for decarbonization. Will current policies open or constrain the opportunities for deep decarbonization?

Many near-term policies will affect long-term decarbonization goals. For example, market-oriented electricity sector reforms (such as reforms on pricing and dispatch rules), if pursued successfully, could strengthen the role of price signals in energy markets, thus improving the economic efficiency of generation and transmission system designs, and improving the capacity of electricity systems to internalize environmental costs. Such an improvement will permit more ambitious investment in renewable generation. Similarly, measures to reduce air pollution will reduce the growth in coal use and therefore carbon emissions. Driven by immediate air pollution concerns, efforts to lower the dependence on coal will also contribute to China's decarbonization goal. Finally, addressing nuclear safety concerns could lay a foundation for expanding nuclear energy in China's overall decarbonization strategy.

However, it is also important to realize that some policies are not aligned with long-term decarbonization objectives. For instance, the present-day system operations and dispatch rules in China's power system constrain renewable generation. In the past decade, renewable feed-in-tariffs have stimulated rapid wind and solar investments, but integrating renewable electricity into the power system remains challenging. Achieving deeper renewable integration requires clear price signals to facilitate investments,

dispatch decisions, and the development of peaker plants to manage intermittent renewable output. In some cases, policies addressing near-term problems may actually create climate dis-benefits. Policymakers should consider the long-term implications of specific energy, economic, and environmental policies on decarbonization, when designing and implementing those policies.

In summary, connecting the near-term and long-term perspectives is essential to preserve the option to decarbonize a nation's energy systems at a later date. Current policies should lay a foundation for longer-term decarbonization.

## b. Reforms in energy and climate governance

Governance and reform was a theme emphasized in all the sessions. The issue of decarbonization involves multiple players, including state-owned enterprises, private enterprises, and individuals. Meaningful reforms need to align the interests of all the major stakeholders. The workshop discussions addressed two key issues associated with governance: (a) what are the linchpins of reforms that can facilitate low carbon development, while aligning the interests of different stakeholder groups? And (b) how to effectively coordinate government agencies to facilitate integrative policy making?

The participants developed consensus on some directions for reforms, such as: breaking monopolies in wholesale and retailing markets, introducing market-based and competitive pricing mechanisms, and gradually eliminating generation quotas. But in practice, each of these reforms could encounter significant barriers. Historically, the generation quotas and fixed wholesale prices were introduced to guarantee capital returns for investors in power generation. Changing the dispatching and pricing mechanisms will increase their risks, and may increase the capital costs for energy development. Thus, the merits and risks of market-oriented reforms need to be put into a socio-political context in which the proponents of greater reliance on markets will confront the advocates of greater government subsidies. Second, there are powerful interests groups in both the electricity and coal industries, and their

interests are not always aligned with market-oriented reforms. Introducing independent system operators and transparent calculation of transmission costs will hurt the profits of grid companies and reduce their control of the system. As several participants pointed out, this observation should not dissuade policymakers from pursuing reform, but should urge them to do so with full awareness of the political challenges.

The issue of coordinated policymaking was discussed in detail in the climate-air pollution co-benefit session. In principle, there are significant co-benefits between climate and air pollution policies. But the development of policies in each area are rarely coordinated. There is noticeable mismatch in the time horizons. Air pollution control policies focus on improving air quality in the short term, while climate policies emphasize on reducing the long-lasting greenhouse gases over several decades. When air pollution becomes an urgent imperative, the government may embrace strategies that have little, or even negative impacts on climate change. Second, air pollution policies are under the jurisdiction of the Ministry of Environment, while climate policies are under the NDRC. There is no formal coordinating mechanism between the two agencies to enhance the effectiveness and co-benefit of reducing conventional air pollution on carbon emissions. Actually, even within NDRC, the department in charge of energy development and the one in charge of climate mitigation do not always coordinate their decisions. Future government reforms need to highlight the importance of integrative policy making across department lines. While China has the capacity to make tough political decisions, decarbonization will require structural and institutional shifts to meet the requirements of a greater reliance on integrative decision-making and greater cooperation between government agencies.

## C. The importance of public participation

Public policymaking in China traditionally relied on command-and-control approaches, and the non-state societal actors had played limited roles in the process. But as awareness of environmental issues arose, thanks, in part, to the facilitation of online social media, ordinary people have

become more active in environmental policy discussions and actions. Simultaneously, the government has become more receptive to the involvement of the public in collaborative efforts to address environmental issues. Topics regarding public acceptance and participation were extensively discussed in both the air pollution and nuclear power sessions.

First, the public outcry about severe air pollution played a critical role in pushing the government to adopt a series of stringent air pollution control policies, some of them having significant climate benefits, such as limiting coal consumption and promoting renewable energy sources. As some speakers pointed out, due to the rising income levels, ordinary Chinese people became more concerned about the quality of living, of which environmental quality is an essential component. In some regions, the government officials feel more pressure to improve environmental quality than from growing GDP. This phenomenon is good news for promoting environmental policies, but it could also backfire if scientists and policymakers do not know how to effectively communicate with the public about the complexities and long-term nature in solving environmental problems. One example is it is difficult to explain to the public that it might take Beijing 15 years to gradually achieve the WHO air quality standards, despite substantial government action.

Public participation and acceptance is an even more important issue in nuclear power development. The participants discussed the NIMBY (not in my backyard) effect in nuclear siting selection and the campaigns against nuclear power plant construction, and compared the strategies taken by China and western countries. Some key lessons from experiences of China and western countries include: (a) regulators need to be meaningfully transparent, i.e. they need to not only make all relevant documentation available to the public, but also let them understand the meaning of the projects, particularly when it comes to site selection and safety issues; (b) public awareness and cooperation requires two-way communication to earn trust and reputation; (c) the public tend to trust safety evaluations conducted by institutions independent of government and industry; to earn this trust, such institutions need to be developed at both the central and regional levels.

## d. Decarbonization and the pursuit of other societal goals

Decarbonization cannot be looked at in isolation from other goals. First and foremost, economic growth is a fundamental need for China. There is already a positive sign that China's carbon emissions have started to decouple from economic growth, owing to economic restructuring and other policies (e.g. coal cap and air pollution policies). The GDP growth for China is projected to slow down, making it easier for China to peak its carbon emissions in the 2025-2030 time horizon.

Second, China is currently considering market reforms. Many of these efforts will benefit long-term decarbonization. For instance, the establishment of a nationwide cap-and-trade system could help build the capacity for an effective and comprehensive carbon market, allowing China to expand its use of market measures to reduce carbon emissions. Market-oriented reforms in the electricity system may also create incentives for investments in transmission and improved grid integration, both of which will allow for greater penetration of renewable energy options.

Third, as mentioned earlier, there are synergies between carbon mitigation and other environmental goals, such as air pollution abatement. The urgency to curb air pollution provides near-term opportunities for reducing coal use and associated carbon emissions. In addition, the increasing public awareness on air pollution issues contributes to an increasing social awareness of environmental issues in general, increasing public support for climate mitigation initiatives.

In summary, there are important linkages between carbon mitigation and other societal goals. The degree to which these goals are aligned determines whether near-term non-climate national priorities will contribute to long term deep decarbonization, and whether climate considerations can be integrated into other near-term policies.

# 4. Conclusion

This workshop tackled some of the most difficult topics in coping with climate change. Scientific research has shown that the warming climate is caused primarily by cumulative, as opposed to short term, carbon emissions, and therefore the ultimate goal of climate policies must be to reduce global carbon emissions to near zero. The discussions in the workshop were focused around two critical questions: (a) how will the decisions China makes today impact its capacity to reduce emissions in the future, and (b) how can weighing longer term goals improve China's energy policy decisions in the next decade? The participants examined China's electricity market reforms, coordination of air pollution and climate policies, and nuclear power development, and they assessed how policy making in the next five years will open up or close opportunities in the future. The most important accomplishments of the workshop were not the answers to these questions, but the framing of the questions in ways that can illuminate long-term strategic policy on climate and energy policies.

There is no silver bullet in addressing the threat of climate change. Different countries, in different stages, face distinctive opportunities and challenges. Before 2030, $CO_2$ emission reduction in the United States will mostly be achieved through substitution of natural gas for coal in power generation. The most important source of $CO_2$ emission reduction in China will be from decreased coal use in heavy industries. Beyond 2030, other challenges will emerge as renewable energy gains a much higher share of the energy mix. New technologies, such as distributed energy sources, battery storage, carbon capture and storage, and nuclear power, all face considerable challenges. It is important for today's policies to preserve, rather than constrain, technology options in the future.

The workshop also highlighted the value of China-U.S. cooperation. The participants drew parallels between the two countries, in terms of economic structure and status, energy endowments, and political processes. While governance in the United States is more decentralized, policy making in China relies on top-down approaches. The United States has highly liberalized power and energy markets, while in China these markets are dominated by state-owned enterprises. Each system has its strengths

and limitations. In the United States, all major energy policies must go through democratic deliberation and scrutiny, and are also susceptible to shifting political priorities. In contrast, China is more able to sustain government support for new technologies and programmatic changes over much longer timeframes. The United States and China have much to learn from each other. Facilitating dialogue between experts from both countries—like through these workshops—becomes particularly important in an international political context that is continually changing.

# Appendix A: Agenda

| May 31 | | | |
|---|---|---|---|
| *10:00-22:00* | *Registration* | | *Lobby, Wenjin Hotel* |
| 19:00-20:30 | **Open Panel: Low Carbon and Energy Policy of Trump's Administration** | | Lecture Hall, School of Public Policy and Management, Tsinghua University |
| | Speaker | **Daniel Schrag** Professor, Director of Science, Technology and Public Policy Program, Harvard Kennedy School<br><br>**Henry Lee** Senior Lecturer, Director of Environment and Natural Resources Program, Harvard Kennedy School<br><br>**Jane Long** Retired, Lawrence Livermore National Laboratory<br><br>**Lan Xue** Professor and Dean, School of Public Policy and Management, Tsinghua University<br><br>**Jun Su** Professor, School of Public Policy and Management, Tsinghua University | |

| June 1: Foundations of Decarbonization in China: A Post-2030 Perspective | | | | |
|---|---|---|---|---|
| 09:00-09:10 | Opening Remarks | Speaker | **Jun Su** Professor, School of Public Policy and Management, Tsinghua University | 4th floor Lecture Hall, Tsinghua University Art Museum |
| | | | **Henry Lee** Senior Lecturer, Director of Environment and Natural Resources Program, Harvard Kennedy School | |
| 09:10-10:30 | **Session 1** | **Elements of a China Decarbonization Strategy (1)** | | |
| | | Moderator | **Jun Su** Professor, School of Public Policy and Management, Tsinghua University | |
| | | Speaker | **Daniel Schrag** Professor, Director of Science, Technology and Public Policy Program, Harvard Kennedy School | |
| | | | **Zheng Li** Professor, Dean of Department of Thermal Engineering , Tsinghua University | |
| | | Free Discussion | | |
| *10:30-10:45* | *Group Photo & Tea Break* | | | |
| 10:45-12:15 | **Session 2** | **Elements of a China Decarbonization Strategy (2)** | | 4th floor Lecture Hall, Tsinghua University Art Museum |
| | | Moderator | **Jane Long** Retired, Lawrence Livermore National Laboratory | |
| | | Speaker | **Xiliang Zhang** Professor, Director of Institute of Energy, Environment and Economy, Tsinghua University | |
| | | Free Discussion | | |
| *12:15-13:15* | *Lunch* | | | |

| | | | | |
|---|---|---|---|---|
| 13:15-15:15 | **Session 3** | **Electricity Regulation Reform and its Impact on Carbon Emissions** | | 4th floor Lecture Hall, Tsinghua University Art Museum |
| | | Moderator | **Henry Lee** Senior Lecturer, Director of Environment and Natural Resources Program, Harvard Kennedy School | |
| | | Speaker | **Bi Fan** Director of Comprehensive Division, State Council Research Office | |
| | | | **Pu Wang** Post-doctoral Research Fellow, Harvard Kennedy School | |
| | | | **Xiaoli Zhao** Professor, School of Business Administration, China University of Petroleum (Beijing) | |
| | | Free Discussion | | |
| *15:15-15:30* | *Tea Break* | | | |
| 15:30-17:30 | **Session 4** | **Impact of Short-term Conventional Pollution Reduction on Long-term Carbon Emissions** | | 4th floor Lecture Hall, Tsinghua University Art Museum |
| | | Moderator | **Ye Qi** Professor, Director of Brookings-Tsinghua Center, School of Public Policy and Management, Tsinghua University | |
| | | Speaker | **Kebin He** Academician of Chinese Academy of Engineering, Professor and Dean of School of Environment, Tsinghua University | |
| | | | **Wei Peng** Post-doctoral Research Fellow, Harvard Kennedy School | |
| | | Free Discussion | | |
| 17:30-18:00 | Closing Session | **Daniel Schrag** Professor, Director of Science, Technology and Public Policy Program, Harvard Kennedy School | | |
| | | **Jun Su** Professor, School of Public Policy and Management, Tsinghua University | | |
| *18:00-20:00* | *Buffet* | | | *Wenjin Hotel* |

| **June 2: Opportunities for Cooperation on Regulating Nuclear Safety and Security** | | | | |
|---|---|---|---|---|
| 09:00-09:10 | Opening Remarks | **Jun Su** Professor, School of Public Policy and Management, Tsinghua University | | 4th floor Lecture Hall, Tsinghua University Art Museum |
| | | **Matthew Bunn** Professor of Practice, Director of Project on Managing the Atom, Harvard Kennedy School | | |
| 09:10-10:30 | **Session 5** | **China's Nuclear Power Development** | | |
| | | Moderator | **Cui Huang** Associate Professor, School of Public Policy and Management, Tsinghua University | |
| | | Speaker | **Yuliang Sun** Professor and Vice Director, Institute of Nuclear and New Energy Technology, Tsinghua University | |
| | | | **Matthew Bunn** Professor of Practice, Director of Project on Managing the Atom, Harvard Kennedy School | |
| | | Free Discussion | | |
| *10:30-10:45* | *Group Photo & Tea Break* | | | |

| | | | | |
|---|---|---|---|---|
| 10:45-12:30 | **Session 6** | **Regulation of Nuclear Safety after Fukushima, and Opportunities for Cooperation** | | 4th floor Lecture Hall, Tsinghua University Art Museum |
| | | Moderator | **Matthew Bunn** Professor of Practice, Director of Project on Managing the Atom, Harvard Kennedy School | |
| | | Speaker | **Bin Li** Senior Engineer and Deputy Director of the Institute of Policy and Regulations, Nuclear and Radiation Safety Center | |
| | | | **Tao Hong** Director of Energy Policy Research Office, Institute of Resources and Environmental Policy Studies, Development Research Center of the State Council | |
| | | | **Allison Macfarlane** Professor of Science Policy and International Affairs, Director of the Institute for International Science and Technology Policy, Elliott School of International Affairs | |
| | | Free Discussion | | |
| *12:30-13:30* | *Lunch* | | | |
| 13:30-15:00 | **Session 7** | **Regulation of Nuclear Security: Cooperation to Meet the Challenges (1)** | | 4th floor Lecture Hall, Tsinghua University Art Museum |
| | | Moderator | **Hui Zhang** Senior Research Associate, Project on Managing the Atom, Harvard Kennedy School | |
| | | Speaker | **Matthew Bunn** Professor of Practice, Director of Project on Managing the Atom, Harvard Kennedy School | |
| | | | **Liming Wang** Senior Engineer and Director of Nuclear Import and Export Division, State Nuclear Security Technology Center | |
| | | | **Troy Wright** Project Manager, Gregg Protection Services | |
| | | Free Discussion | | |
| *15:00-15:15* | *Tea Break* | | | |
| 15:15-17:00 | **Session 8** | **Regulation of Nuclear Security: Cooperation to Meet the Challenges (2)** | | 4th floor Lecture Hall, Tsinghua University Art Museum |
| | | Moderator | **Allison Macfarlane** Professor of Science Policy and International Affairs, Director of the Institute for International Science and Technology Policy, Elliott School of International Affairs | |
| | | Speaker | **Shangui Zhao** Senior Engineer, Nuclear and Radiation Safety Center | |
| | | | **Frederick Morris** Chief Scientist, Pacific Northwest National Laboratory | |
| | | Free Discussion | | |
| 17:00-17:30 | Closing Session | **Matthew Bunn** Professor of Practice, Director of Project on Managing the Atom, Harvard Kennedy School | | |
| | | **Jun Su** Professor, School of Public Policy and Management, Tsinghua University | | |
| *17:30-20:00* | *Dinner* | | | *Quanjude Restaurant* |

# Appendix B: Participants

**Jiaqi Zhang**, Research Associate, China Institute of Nuclear Information and Economics

**Sufang Zhang**, Professor, College of Business Administration, North China Electric Power University

**Xiaoling Zhang,** Associate Professor, Department of Public Policy, City University of Hong Kong

**Zuoyi Zhang**, Professor, Director and Chief Scientist, Institute of Nuclear and new Energy Technology, Tsinghua University

**Yongqiang Zhao**, Deputy Director of Renewable Energy Center, Energy Research Institute, National Development and Reform Commission

**Biyu Zhou**, Professor, College of Economics and Management, Zhejiang University of Technology

**Lili Wu**, Lecturer, School of Business Administration, China University of Petroleum-Beijing

**Lan Xue,** Professor and Dean of School of Public Policy and Management, Tsinghua University; Director, China Institute for S&T Policy; Deputy Director, China Institute for Strategic Studies on Engineering and Technology Development

**Qiquan Yang**, Chairman, China Society for S&T Indicators

**Qiang Yao**, Professor, Department of Thermal Engineering, Tsinghua University

**Jiahai Yuan**, Professor, College of Business Administration, North China Electric Power University

**Rong Zeng,** Professor, Director, Department of Electrical Engineering, Tsinghua University; Director, Energy Internet Research Institute, Tsinghua University

**Xunmin Ou**, Associate Professor, Institute of Energy, Environment and Economy, Tsinghua University; Deputy Director, China Automotive Energy Research Center, Tsinghua University; Deputy Sectary General, Energy System Engineering Committee, China Energy Research Society

**Fei Teng,** Associate Professor, Institute of Energy, Environment and Economy, Tsinghua University; Deputy Director, Tsinghua-Berkeley Joint Research Center on Energy and Climate.

**Yajun Tian**, Project Manager and Senior Engineer, National Institute of Clean-and-Low-Carbon Energy

**Yi Wang**, Research Fellow and Director, Institute of Policy and Management, Chinese Academy of Sciences; Vice President, Institutes of Science and Development, Chinese Academy of Sciences; Member, Standing Committee of the 12th National People's Congress of China.

**Dongsheng Wu**, Research Fellow and Associate, Environment and Natural Resources Program, Harvard Kennedy School, Belfer Center for Science and International Affairs; Fellow, Asia Energy and Sustainability Initiative, Harvard Kennedy School, Ash Center for Democratic Governance and Innovation

**Jun Wu**, Research Fellow and the Deputy Director, Center for Strategic Studies of China Academy of Engineering Physics

**Ying Fan**, Professor of Management Science, Dean, School of Economics and Management, Beihang University; Vice President, International Association for Energy Economics; Vice President, Chinese Society of Optimization, Overall Planning and Economic Mathematics; President, Chinese Society of Low Carbon Development Management; Director, Center for Energy & Environmental Policy Research

**Shulin Gu**, Research Fellow, Institute of Policy and Management, Chinese Academy of Sciences; Advisory Research Professor, China Institute of Science and Technology Policy, Tsinghua University; Adjunct Professor, Management School, Zhejiang University.

**Jinqiu He**, Professor, School of Public Policy and Management, Tsinghua University; Secretary-general, Center for Science, Technology and Education Policy; Executive Secretary-general, China Institute of Science and Technology Policy

**Zheng Liang** Associate Professor, School of Public Policy and Management, Tsinghua University; Deputy Director, China Institute for Science & Technology Policy, Tsinghua University

**Tianshu Liu**, Deputy Director, Department of Nuclear and Radioactive Waste, Ministry of Environmental Protection

**Xi Lu**, Associate Professor, School of Environment, Tsinghua University

**Yue Guo**, Postdoctoral Research Fellow, Project on Managing the Atom, Belfer Center for Science and International Affairs, Harvard Kennedy School

**Zhimin Mao**, Postdoctoral Research Fellow, Environment and Natural Resources Program, Harvard Kennedy School

**Yunsheng Bai**, Senior Research Fellow and Vice Director, China Institute of Nuclear Information and Economics; Director, Nuclear Industry Strategic Research Center

**Qixin Chen**, Associate Professor, Department of Electrical Engineering, Tsinghua University; Vice Director, Energy Internet Research Institute, Tsinghua University; Vice Director, Tsinghua-Sichuan Energy Internet Research Institute

**Yixin Dai**, Associated Professor, School of Public Policy and Management, Tsinghua University

**Maosheng Duan**, Research Fellow, Institute of Nuclear and New Energy Technology; Director, China Carbon Market Center, Tsinghua University

**Shangui Zhao**, Senior Engineer and Director, Nuclear Fuel Cycle Division, Nuclear and Radiation Safety Centre

**Xiaoli Zhao**, Professor, School of Business Administration, China University of Petroleum-Beijing; Director, Center for Low Carbon Economy and Policy; Secretary-general, Branch of Energy & Resource Systems Engineering, Systems Engineering Society of China.

**Ben Martin**, Associate Fellow, Centre for Science and Policy, University of Cambridge

**Nickolas Roth**, Research Associate, Project on Managing the Atom, Belfer Center for Science and International Affairs, Harvard Kennedy School

**Tao Ren**, Pre-doctoral Research Fellow, Science, Technology, and Public Policy Program, Harvard Kennedy School; Ph.D. Candidate in public policy, Tsinghua University

**Bin Li**, Senior Engineer and Deputy Director, Nuclear and Radiation Safety Center, Ministry of Environmental Protection of China

**Zheng Li**, Professor and Dean, Department of Thermal Engineering, Tsinghua University; Director, Tsinghua BP Clean Energy Research and Education Center

**Ye Qi**, Professor of Environmental Policy and Management, Tsinghua University

**YuLiang Sun**, Professor and Vice Director, Institute of Nuclear and New Energy Technology, Tsinghua University

**Liming Wang**, Senior Engineer and Director, Nuclear Import and Export Division, State Nuclear Security Technology Center

**Xiliang Zhang**, Professor, Institute of Nuclear and New Energy Technology, Tsinghua University; Director, Institute of Energy, Environment and Economy, Tsinghua University; Member, Standing Committee, China Energy Research Society; Vice President, Energy Economy and Management Branch, Chinese Society of Optimization, Overall Planning and Economical Mathematics; Vice Director, Chinese Renewable Energy Industries Association.

**Troy L. Wright**, Project Manager, Centerra Group LLC

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

**Bi Fan**, Director, Comprehensive Division, State Council Research Office

**Kebin He**, Academician, Chinese Academy of Engineering; Cheung Kong Scholar Chair Professor, Dean of School of Environment, Tsinghua University

**Tao Hong**, Senior Economist and Director, Energy Policy Research Office, Institute of Resources and Environmental Policy Studies, Development Research Center of the State Council; Member, Policy Research Committee, China Natural Resources Society

**Cui Huang**, Associate Professor, School of Public Policy and Management, Tsinghua University; Vice Director, Center for Science, Technology & Education Policy, School of Public Policy and Management, Tsinghua University

**Allison M. Macfarlane**, Professor of Science and Technology Policy, George Washington University; Director, Center for International Science and Technology Policy; Elliott School of International Affairs, George Washington University

**Frederic A. Morris**, Research Scientist, Pacific Northwest National Laboratory; Senior Sustainability Advisor, Office of Radiological Security, U.S. Department of Energy, National Nuclear Security Administration; Member, Council on Foreign Relations; Member, Institute of Nuclear Materials Management; Member, Pacific Council on International Policy; Member, World Institute for Nuclear Security.

**Hui Zhang**, Senior Research Associate, Project on Managing the Atom, Belfer Center for Science and International Affairs, Harvard Kennedy School

**Jane Long**, Principal Associate Director-at-Large (ret.), Lawrence Livermore National Laboratory; Senior Contributing Scientist, Environmental Defense Fund; Co-chair, California Council on Science and Technology, California's Energy Future committee.

**Pu Wang**, Giorgio Ruffolo Postdoctoral Research Fellow in Sustainability Science, Environment and Natural Resources Program, Belfer Center, Harvard Kennedy School

**Jiankun He**, Dean and Professor, Institute of Low Carbon Economy; Vice Director, National Expert Committee for Climate Change

**Daniel Schrag**, Sturgis Hooper Professor of Geology, Professor of Environmental Science and Engineering, Harvard University; Director, Harvard University Center for the Environment; Director, Science, Technology and Public Policy Program, Belfer Center for Science and International Affairs, Harvard Kennedy School.

**Henry Lee**, Director, Environment and Natural Resources Program, Belfer Center for Science and International Affairs, Harvard Kennedy School; Faculty Co-Chair, Energy Technology Innovation Policy Project, Belfer Center; Senior Lecturer in Public Policy, Harvard Kennedy School

**Matthew Bunn**, Professor of Practice, Harvard Kennedy School; Member, Nuclear Energy Advisory Committee, Department of Energy; Consultant, Pacific Northwest and Oak Ridge National Laboratories; Member, Board of Directors, Arms Control Association

**Jun Su**, Professor, School of Public Policy and Management, Tsinghua University; Director, Center for Science, Technology and Education Policy, Tsinghua University; Deputy Director, Advisory Committee of the Public Administration, Ministry of Education; Associate, Harvard Kennedy School; Senior Research Fellow, Fletcher School of Law and Diplomacy, Tufts University

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