Clean-energy development in China

By Jane Qiu

In June, China announced its 2030 target to cut its greenhouse-gas emissions per unit of gross domestic product by 60%–65% from 2005 levels. To achieve the goal, it would increase the share of non-fossil fuels as part of its primary energy consumption to 20% by 2030 and aim to peak emissions around the same time. As world’s largest carbon emitter, the announcement is widely hailed not only as a strong impetus for the UN climate talks, which are convened in Paris this month, but as a solution to the country’s unprecedented choking pollution.

In a forum chaired by National Science Review’s executive associate editor Mu-ming Poo, four panelists from diverse backgrounds discuss how clean-energy development could help China to fight against air pollution and meet its 2030 target, what sorts of policies need to be in place, and what the main challenges are.

Xinhe Bao
Physical chemist of Chinese Academy of Sciences’ Dalian Institute of Chemical Physics

Kejun Jiang
Energy researcher at the Institute of Energy Research, National Development and Reform Commission

Longlong Ma
Energy researcher and deputy director of Chinese Academy of Sciences’ Guangzhou Institute of Energy Conversion

Ye Qi
Policy researcher on climate and energy at Tsinghua University

Mu-ming Poo (Chair)
Neuroscientist and director of Chinese Academy of Sciences’ Institute of Neuroscience

KEY SOURCES OF CHINA’S AIR POLLUTION

Poo: China’s air pollution has attracted worldwide attention in recent years. What are the key sources?
Bao: Coal burning is certainly the main source of air pollution nationwide: burning of one tonne of standard coal can emit about three tonnes of carbon dioxide—along with other pollutants such as sulphur dioxide and nitrogen oxides.
Ma: Air pollution in China is extremely complicated. Smog can be caused by vehicle emissions, the burning of coal and biomass, dust and rubbish incineration. Their relative contribution in different regions can be quite different. What makes things really complicated is that there are primary pollutants, such as sulphuric dioxide and carbon monoxide, which are directly emitted by their sources, and secondary pollutants, such as ozone and particulate matter 2.5 (PM2.5), that are formed by photochemical reactions between a range of different precursors in the atmosphere.

Poo: There have been some debates about whether vehicle emissions or coal burning is the main contributor of the notorious Beijing smog. Is this still a point of contention?
Jiang: We have done a lot of research on this, mainly focusing on primary pollutants from both energy sectors and non-energy sectors, such as agriculture, cooking, dust and construction sites around Beijing. While there are still some uncertainties, the recent release of primary pollutant sources in the Beijing–Tianjin–Hebei region is roughly correct and fall into the realm of our analyses.

Poo: So what are the key primary pollutant sources in the Beijing–Tianjin–Hebei region?
Jiang: Based on recent studies on the sources of PM2.5-related gases, emission from road transport, coal burning, chemical...
products manufactures, agriculture, biomass burning, construction site and cooking are the major sources.  

Poo: Are there some regional differences in terms of pollution sources across the country?  

Jiang: Indeed. According to our models, for instance, coal burning constitutes a small percentage of primary pollutants in Beijing. By contract, it’s a main source of pollution in provinces like Hebei, Shaanxi, Jiangsu and Anhui. When we assess whether China’s Anti-Air Pollution Plan can achieve its target, we have to do this kind of analyses province by province and tie the pollution sources to financial investment.  

Qi: I’m not as optimistic. I think there is still a lack of consensus about pollution sources. Different studies can vary widely even regarding places like Beijing, which will impact policy making. Some studies show that secondary pollutants can constitute as much as 80% of all pollutants in PM2.5 in Beijing. If this is the case, there can be important policy implications.  

Poo: China has closed a lot of energy-inefficient factories and power plants. This should have a very important role in tackling air pollution. Is it a reasonable expectation?  

Qi: This certainly can make a difference. In the first half of this year, the concentration of PM2.5 in Beijing dropped by 9.4% compared to the 2014 level for the same period. This may be related to the fact that a lot of factories in Hebei province have been closed as well as government’s continuing efforts to replace coal with natural gas in Beijing.  

"With such dense population in China, the underlying risks [of rapid development of nuclear energy] must not be underestimated."

—Ye Qi

“CHINA’S ENERGY STRUCTURE AND CLEAN-ENERGY PLANS  

Poo: What’s China’s energy structure like?  

Bao: The energy structure in China is very different from that in Europe and the US in its heavy reliance on coal. And coal will be China’s key energy source in the foreseeable future. According to the strategic energy plan of the National Development and Reform Commission (NDRC), the percentage of coal in the country’s total energy consumption will be maintained at the level of 50%–60% by 2030. This is something everybody wants to change, but it’s not going to happen overnight.  

Poo: So how can we reduce emissions then when we will continue to rely heavily on coal?  

Bao: While stressing the importance of renewable energy, we should also focus on how to optimize the use of coal and reduce its environmental impact. Over 80% of power stations in China are powered by coal and the efficiency is rather low, mostly around 36%–40% and the better ones up to 47%. So boosting the efficiency of coal burning is key to tackling air pollution in the near future. There is a promising technology called integrated gasification combined cycle (IGCC), which turns coal into gas, such as hydrogen and carbon monoxide, and removes impurities from the gas before combustion. This can increase the efficiency to 57%. The problem is the technology is not ready for commercialization and it’s still very expensive.  

Qi: I agree: coal will continue to be China’s key energy source in the foreseeable future. This is a consensus that most researchers and policy makers agree upon. Equally important is the fact that there has been rapid reduction in the energy intensity, especially in the past 5–10 years. The change is happening, which will help to tackle air pollution. In particular, China and the US signed the Joint Announcement on Clean Energy and Climate Change last November, in which China vows to increase the share of non-fossil fuels in its primary energy consumption to 20% by 2030. This is a very ambitious target. China also made the Intended Nationally Determined Contributions (INDC) pledge this June to cut its carbon emissions by 60%–65% from 2005 levels by 2030. If realized, this would drastically transform China’s energy structure.  

Ma: Regarding China’s energy structure, coal constitutes 67% of total energy consumption, crude oil 18%, natural gas 5%, clean energy 8% (such as hydropower, nuclear, solar, wind and biomass). China’s plan to boost clean energy in the total energy mix is very ambitious, but it’s still quite a small proportion. So I agree with Bao: the top priority right now is to boost the efficiency of coal use.  

Poo: What is the prospect of various types of clean energy?  

Ma: Hydropower will constitute a large proportion of the future clean-energy mix, but there is a limit to how many big hydropower plants, such as the Three Gorges Dam, we can build. NDRC has ambitious plans for developing nuclear power, but the pace is not very fast. Wind and solar power are developing fast, but they are mainly for electricity generation. According to the forecast by Biomass Innovation Alliance, the Chinese utility of biomass fuel can be equivalent of 100 million tonnes of standard coal by 2020 and 200 million tonnes by 2030, about 4% of total energy consumption (or 5 billion tonnes of standard coal). All of them are quite expensive at the moment. The key is to develop the technology further as well as the economics. Of course, China’s incentive policies and industrial guidance are critical.  

Jiang: We are involved in the 13th five-year plan regarding China’s energy structure by 2030. We are quite optimistic about the 2030 target because the consumption of coal has dropped markedly in recent years. The country’s coal use reached the peak level in 2014, with a 2.9% reduction compared to the previous year, even though the total energy use increased by 2.2%.  

Poo: How will this change in the future?  

Jiang: We are assessing the possible reduction in coal use by 2020. Our scenario analyses show that the reduction would be in the range of 400–800 million tonnes compared with that in 2014, in which case the percentage of coal in primary energy consumption would drop from the current level of 66% to 55%–58% by 2020, and less than 50% by 2030. China’s increase in
energy demand has now slowed down, about less than 1% in the first half of the year. If this trend continues, we should be able to keep the consumption of coal in check, especially with the rising use of renewable energy, nuclear energy and natural gas.

**CONSTRAINTS OF CLEAN-ENERGY DEVELOPMENT IN CHINA**

**Poo:** Nuclear energy represents a promising form of clean energy. What are the main constraints for its development in China?

**Jiang:** China used to have ambitious plans for nuclear energy, which is relatively clean and safe, but was slowed down because of the Fukushima nuclear accident. It’s started to pick up the pace of development again this year. Its growth is very fast and exceeds our projection. We are quite optimistic about its contribution to China’s clean-energy mix in the future.

**Ma:** There are two main constraints. China’s nuclear resources are not very rich and we rely heavily on import. Moreover, we are still in the process of developing safer and more efficient nuclear technology. So right now, we are not ready to use nuclear energy on a large scale.

**Bao:** A few other issues also affect the pace of development. First, nuclear-power stations require massive amounts of investment and can’t be built overnight. Second, the potential risks and environmental impact are quite substantial, even with third-generation or more advanced technology, which is a great concern for the public. Third, it is still unclear what is the best and safest way to treat nuclear waste, which constitutes 95% of nuclear raw materials. Nuclear energy is indeed a promising form of clean energy for China but it won’t any time soon reach the level as in countries like France where it gives rise to over 70% of the country’s energy consumption.

**Poo:** How about the investment in R&D of nuclear energy?

**Bao:** The investment was quite limited in the past but the level has risen in the last few years. The Chinese Academy of Sciences (CAS), for instance, has a major research programme at the cost of 2.5 billion yuan aiming to develop nuclear energy using thorium, of which China has rich reserves. Another major area of research at CAS is to boost the efficiency of uranium utilization, which will help to reduce nuclear waste. But we still have a long way to go.

**Qi:** Experts have different views about the pace of nuclear-energy development in China. Some think that it’s not fast enough and that China should aim for a higher proportion of nuclear energy in the future energy mix. Others think, however, that it’s too fast and concern with its safety. If China reaches its 2030 target of increasing the share of non-fossil fuels to 20%, about 800–1000 GW of additional power generation capacity, then the capacity of nuclear energy, which is set to constitute 35%, it’s very high percentage. No other countries have achieved such fast, large-scale development of nuclear energy. With such dense population in China, the underlying risks must not be underestimated. The risk assessment and environmental impact must be done properly and should not be carried out only by scientists and engineers.

**Poo:** What’s the potential of biomass energy?

**Ma:** In contrast to hydropower, wind and solar power that are more suitable for generating electricity, biomass is better used as renewable fuel. Right now, biomass can be used as gas, liquid and high-density solid fuel—the latter two are more promising and more suitable for engines that are in use currently. The main problem lies in the economics. We could convert animal manure to methane with a purity of over 97%, which is comparable to natural gas. The technology is ready for commercial operation but it’s very costly, about 2.5 yuan per 1000 litre, which cannot compete with imported natural gas. But if we take into account of the expenses for treating animal manure or the environmental cost of air, water and soil pollution if not properly treated, it then should be rather economical. Regarding liquid fuel, mainly biodiesel, the cost of primary materials is quite high. So it may be quite challenging to have wide applications, but the economics could be enhanced if we also produce a few other chemicals alongside.

“China still lags behind developed countries in terms of truly innovative technologies.”

—Xinhe Bao

**POLICY SUPPORT FOR CLEAN-ENERGY DEVELOPMENT**

**Poo:** This brings us to the issue of government support and incentive policies. How is China encouraging the development of clean energy?

**Qi:** There are a lot of incentive policies in terms of land use, tax and financing from both the central and provincial government. The central government has set very clear and ambitious targets of emission reduction and clean-energy development. The investment on clean energy from governments and private sectors in China is massive—the biggest in the world—constituting about 25% of the global investment.

**Ma:** I think there is much room for improvement. Taking biomass energy for instance, we only talk about the economics of the product, without taking into account of the environmental impact that animal manure would cause if not treated properly. But no government agencies have combined the two when calculating the cost.

**Qi:** China has a lot of supporting policies, which, in my view, is unprecedented. Since last year, for instance, the Ministry of Science and Technology (MOST) has stepped up investment in photovoltaic cells. As Ma mentioned, there has been a lot of technological progress in, say, biomass energy. But I lose confidence in China when I went to visit a few industrial-scale biofuel projects in Brazil. It’s not about the technologies but their...
applications. Brazil has invested vast areas of land to produce sugarcane, which they call energy cane, for biofuel. The scale of applications really puts China in shade.

**Jiang:** EU has set the target to reduce greenhouse-gas emissions by 80% by 2050 compared with 1990, with nearly net zero emissions from energy activities. Clean energy is key to achieving the target, so everything moves in that direction. By contrast, China hasn’t set a goal beyond 2030, which is still work in progress and needs to consider various factors such as cost, technological progress, and energy demand. This lack of longer term goal really affects China’s strategic planning.

**Ma:** Biomass-derived jet fuels are an example of how incentive polices could stimulate research and development. A lot of companies in the West are keen to collaborate with China on the production of jet fuels using biomass. This is related to carbon tax. In Europe, carbon tax of civil aviation could be reduced if clean energy is used, providing the incentives for companies to invest in this kind of technologies.

**Jiang:** China really should step up investment on research and development in areas such as IGCC, biomass energy, grid technology, nuclear power, affordable power-generation systems and new materials for solar cells. The US and Europe are leaders of basic research on clean energy, which is ultimately the driving force of technological breakthrough.

"China really needs a long-term strategic plan at the top and decides what’s best for the country, rather than following the crowds."

—Longlong Ma

**CLEAN-ENERGY RESEARCH AND DEVELOPMENT IN CHINA**

**Poo:** What’s the situation of China’s clean-energy research?

**Ma:** China has invested heavily on all sorts of clean-energy research. In the field of biomass, which I’m most familiar with, this includes biotechnology, thermal chemical and chemical catalysis technologies—which could lead to novel fuels or improving the efficiency of biomass energy. The technologies for producing jet fuels from biomass materials, such as straws, are progressing especially rapidly.

**Bao:** In many areas of research, China still lags behind developed countries in terms of truly innovative technologies. Researchers in the West have recently developed a new technology to make solar cells using perovskite, which can increase the efficiency of converting sunlight to electricity to 20% in a very cheap way. Why hasn’t this kind of progress taken place in China, which has invested heavily on solar power?

**Poo:** Has this kind of technological obstacles impeded the development of clean energy in China?

**Bao:** Indeed. Another example is wind energy. China has built numerous wind turbines, but lacks reliable technologies to store the energy and connect to the grids. So many newly built wind turbines are not used at all, resulting in *qifeng* (‘abandoning the wind’). But there has been some encouraging progress. Researchers in our institute, for instance, are now able to store wind energy on the scale of 10 MW—probably the largest demonstrated scale in the world—and are heading for 100 MW.

**Poo:** What are the progresses in other areas of research?

**Bao:** I can mention two promising technologies that I’m familiar with. The first one is the technology to convert coal to methanol and then to ethylene. In the past, we get ethylene and propylene from crude oil; to get one tonne of ethylene needs to refine 10 tonnes of crude oil. China needs 38 million tonnes of ethylene a year, and would build the refinery capacity of 380 tonnes of crude oil per year. With the new technology, we could get ethylene from coal, which is a significant breakthrough. Now a lot of US companies are very interested in this technology. A caveat is that this technology needs a lot of water and emits a lot of carbon dioxide. So it remains to be seen how sustainable the technology is. It’s an open question. Second, our research group is able to produce ethylene from natural gas in a single step, which we published in *Science*. This has been the focus of research worldwide for decades. Major chemical companies around the world are very interested in this technology. These novel findings are very important for the development of selective routes for the direct utilization of methane, and would bring a truly step forward in the implementation in the chemical and clean energy industries.

**Ma:** Regarding biomass, the main progress has been to increase the purity of manure-derived methane to 97%, the standard that could be used by vehicles. Most middle-sized and large farms are taking up this technology. Moreover, there are technological breakthroughs to convert cellulose to ethylene and propylene, common intermediate chemicals for jet fuels and other products. We can now produce one tonne of jet fuel from 10 tonnes of straws at the cost of 10 000 yuan, which is a lot cheaper than using other materials such as triacylglycerides.

**Qi:** On the side of application, there has been some significant progress in high-efficiency electricity generation using coal, as exemplified by the Shanghai Waigaoqiao Power Station Three, which is one of the most energy-efficient power stations in the world. There has also been some encouraging progress in carbon capture and storage at the US–China Clean Energy Research Centre, which was established in 2009.

**LOOKING AHEAD: OBSTACLES AND CHALLENGES**

**Poo:** What are the main challenges for clean-energy development in China?

**Qi:** From the policy perspective, a main constrain is that China doesn’t have an emission-reduction target beyond 2030. From a global perspective, G7 had a joint statement on 8 July to phase out fossil-fuel use by the end of the century. It is debatable how seriously they will take the target or how realistic it is, but I think...
this does send a signal to the world at large. China really needs to decide whether it will go along with it because this will determine the country’s long-term strategic planning and policies.

"There is a lack of consensus in China about climate change even among scientists."
—Kejun Jiang

Jiang: Climate change is likely to be the only driver to push us to reduce the use of fossil fuel, which is also the motivation behind the G7 statement in July. I don’t think China is very clear about how it will go about tackling climate change. Reduction in carbon-dioxide emission is a key element, but there is no clear consensus in China about long-term targets. If China is set to drastically cut carbon emissions by 2050, it will impact policies and people’s behaviours in the next 35 years. The lack of long-term target is a big obstacle to clean-energy development.

Poo: Some senior Chinese scientists—such as Zhongli Ding, President of the University of Chinese Academy of Sciences—don’t seem to think that climate change is driven by human activities, which is very shocking to me. So do we have consensus about climate change in China? If not, wouldn’t this affect China’s commitment to clean energy?

Qiu: There is good consensus about the causes of climate change in China, which is far higher than in the US. I think the view you mentioned is an outlier and does not represent the majority of scientists in China.

Bao: I’m not sure I agree. People in the US—either scientists, government officials or the general public—can be very outspoken, and so we get to hear diverse views. By contrast, we don’t tend to hear different opinions in China, especially in official occasions—which may explain why we appear to have greater consensus on climate change than in the US. In my experience, a lot of the climate and clean-energy policies are not implemented effectively, and a lot of people just go through the motion. This may be related to whether they genuinely believe in the importance of such policies.

Ma: China really needs a long-term strategic plan at the top and decides what’s best for the country, rather than following the crowds, especially the US. It must focus on basic research. It’s the wellspring of technological breakthroughs.

Jiang: China is still deliberating whether cutting greenhouse-gas emissions will be its long-term goal beyond 2030 and how we should go about it in the 13th five-year plan which begins next year. Once they are decided, the government will instigate relevant policies and provide guidance for basic research. I agree with Bao: there is a lack of consensus in China about climate change even among scientists. We really need to work on this.

Jane Qiu writes for NSR from Beijing.