Preface 1

We have been collaborating with BP for over 10 years. Our partnership combines Tsinghua's academic research strength with BP's international energy expertise, applied to some of China's biggest development challenges. As China's economy is going through a new era, it also brings new challenges to energy security, clean and low-carbon energy utilisation, and environmental protection. In the last 5 years, the collaboration between Tsinghua and BP has made steady progress towards systematic analysis of these challenges, based on sound engineering principles, across several topics: analysing the energy embodied in infrastructure and the inefficiencies of overcapacity building with shorter useful lifetime or less operating time; revealing the huge disparities in regional energy consumptions, and the relationship between technology choices and changing energy prices. Our improved understanding of these outcomes is expected to help better plan China's energy future.

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Preface 2

China has become an economic superpower over the last 20 years and will continue to grow substantially for the foreseeable future. All nations require energy to fuel economic growth. It is increasingly obvious that China needs to find a more sustainable path to power this economic growth.

This publication has attempted to describe the scale and complexity of China's energy system. We have used Sankey diagrams to visualise the energy flows across the economy. We have also looked to visualise and categorise the differences between China's provinces. China's provinces extend over a vast geography and are at different stages of economic development. Regional planning and inter-regional optimisation will be essential for planning future infrastructure that will allow China as a whole to optimise and avoid overcapacity and inefficiency.

Consistent with this analysis, we have introduced our energy systems modelling approach and demonstrated its application to the power sector. Our power model can help to optimise the overall design of the power system and reveal how different future investment choices only emerge, e.g. natural gas-fired power, as the level of detail is increased, such as regional, seasonal, and diurnal demand factors are considered. We also begin to look at options for mitigating carbon and the major role that renewables and natural gas could play as well as carbon pricing.

Planning a more sustainable future is now critically important for China as there are major risks that need to be dealt with today. Three of the key challenges are as follows:

- The Chinese economy is exposed to overcapacity, including that of energy and associated infrastructure.
- Urban air quality regularly exceeds WHO recommended limits by up to an order of magnitude.
- Coal dominates the energy supply mix, with major environmental consequences for air and water quality, as well as the global climate.

There are also three major considerations:

- China is heterogeneous with energy-related issues varying by province. No single national policy will fit each province's economic and environmental needs.
- Renewables are growing rapidly in China, due to the policy emphasis on energy security, the environment, and the global climate but managing their intermittency needs to be modelled in great detail hour by hour, region by region.
- The growth in energy demand is slowing as China has industrialised and looks to upgrade its economy. Future growth will be policy-dependent, particularly related to China's commitments to carbon emissions reductions under the Paris Agreement.

This leads us to our major recommendations for prioritisation of strategic options to deal with the three challenges:

1. To deal with overcapacity:
   Planners must consider differences between provinces and consider inter-regional imports and exports of energy and the related infrastructure to develop a more efficient and cost-optimised configuration.

   There should be a focus on building energy infrastructure that prioritises quality over quantity, and that delivers long-term competitiveness over short-term GDP growth.

2. To deal with environmental challenges:
   China can learn much from North America and Europe in dealing with the environmental impact of industrial development. The technical solutions are available.

   The enforcement of environmental regulations and the use of clean-up technologies are essential.

   Reducing the use of energy through improvement of energy efficiency in industry, buildings, and transport should be prioritised.

   Distributed direct burning of raw coal with no pollution control measures should be replaced as a priority with clean natural gas or demand side electrification.

3. To diversify the energy supply mix to a more low-carbon future:
   China must accelerate the growth in indigenous unconventional shale gas supply, and that requires restructuring of the market, and provide open access to attract investors and participants with the appropriate expertise.

   China could then better prioritise the use of natural gas in power and balance intermittent renewable supply. Even without indigenous gas supply, the import of natural gas to provide cleaner power has significant environmental and operational merits.

   The path to a more low-carbon future will requires further exploitation of renewable energy and the development of advanced gas turbine and nuclear capabilities. Where possible, China should look to maximise the use of waste biomass locally for heat and power.

Although the share of coal in total energy mix will decrease, it will not disappear overnight, especially because many coal facilities such as coal power plants are brand-new and a lot of carbon and energy have been invested in their construction. While it is always important to ensure their operational efficiency, it is also imperative for coal power plants to back up renewable energy to optimise carbon emissions of the whole system.

Carbon capture and storage has many challenges and is far from being proven. Therefore relying on CCS to mitigate the long-term use of coal carries significant uncertainty. So it is necessary to continue to strengthen research on CCS.

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