ASSESSING POSSIBLE GENERATION PORTFOLIOS FOR CHINA'S FUTURE CARBON CONSTRAINED ELECTRICITY INDUSTRY

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Overview

Strong economic growth in China over the past decade has led to significant increase in electricity demand and total installed generation capacity, both of which are now ranked highest in the world. Due to the significant share of coal-fired power plants in the generation mix, China is also the world's biggest greenhouse gas emitter, although on a per capita basis China still ranks relatively low compared to OECD countries. In addition, the rise in regional air pollution, particularly NO_x, SO_2 and particulate matter (PM), has caused significant adverse impacts domestically. The electricity sector has been identified as the largest contributor to China's greenhouse gas and regional air pollution. The Chinese Government has outlined the plan to curb the rise in both greenhouse emissions and local air pollutants by promoting hydropower development, gradually increasing the share of nuclear power, accelerating the deployment of renewable technologies particularly wind, solar and biomass. A number of policy mechanisms have been introduced to achieve this, which include renewable energy targets and the establishment of a national carbon emissions trading market. This plan aims to increase the renewable energy power generation capacity by 160 GW and achieving at least 20% of total power generation, while reducing coal-fired electricity generation by around 65% in the 12th five year period [1]. These plans would have important implications for future generation investment in China's electricity industry. There are however considerable challenges in achieving this ambitious target due to the slow progress in reforming the electricity sector, which is illustrated by the current generation dispatch approach that is still based on allocating shares of generation. Such dispatch model does not reflect the true generation costs and hinders the efficient dispatch of renewable generation. In addition the current electricity price regulations hinder the pass-through on carbon prices, which makes it difficult for the electricity industry to recover their costs.

Given these backgrounds and nature of generation investments in the electricity sector, this paper aims to assess how different generation investment priorities might impact on costs and associated risks and emissions in order to highlight the diversified development prospects for China's electricity industry. This modelling study analyses different future generation portfolio options in China in 2030 under highly uncertain fuel prices, carbon pricing policy, electricity demand and plant capital costs across multiple industry objectives involving expected cost, cost risk and emissions. In particular, it focuses on the impact of emission pricing on the electricity sector investment.

Methods

This paper employs a probabilistic generation portfolio investment modelling tool which was first developed in [2] to assess different possible future generation portfolio options in China's electricity industry for 2030 under highly uncertain fuel prices, carbon pricing policy, electricity demand and plant capital costs. The modelling tool employs Monte Carlo Simulation (MCS) techniques to formally accounts for key uncertainties in generation investment and planning decision-making. With MCS techniques, outputs for each of the possible future generation portfolios consist of many thousands simulated overall generation costs and environmental emissions including CO_2, NO_X and SO_2. These outputs can, therefore, be represented by probability distributions.

The study explores four different investment scenarios for PV and wind generation for 2030 ranging from 10% to 50% combined PV and wind energy penetration. These scenarios and corresponding total renewable penetrations (including hydro) are summarised in Table 1. Note that as the renewable penetration increases, the growing levels of variable PV and wind generation may result in energy spillage. Seven new generation options for 2030 are assumed in the modelling: coal, combined cycle gas turbine (CCGT), nuclear, Integrated Gasification Combined Cycle (IGCC), wind (onshore), PV (fixed flat plate) and hydro generation.

Table 1. Different renewable penetration scenarios considered in the modelling.

Renewable penetration scenario (%)	% PV energy	% Wind energy	Spilled PV and wind (%)	Hydro (%)	Others (thermal) (%)
20	5	5	0	12	78
30	10	10	0	12	68
40	10	20	0.03	12	58
60	20	30	5	12	42

Results

The details of the least cost portfolio for different expected carbon prices in 2030 are shown in Fig. 1. In the case without a carbon price, the least cost generation portfolio comprises a significant share of coal-fired generation and only small amount of gas-fired, PV and wind generation while nuclear and IGCC are deemed too expensive, and hence are not featured as part of the least cost portfolio.

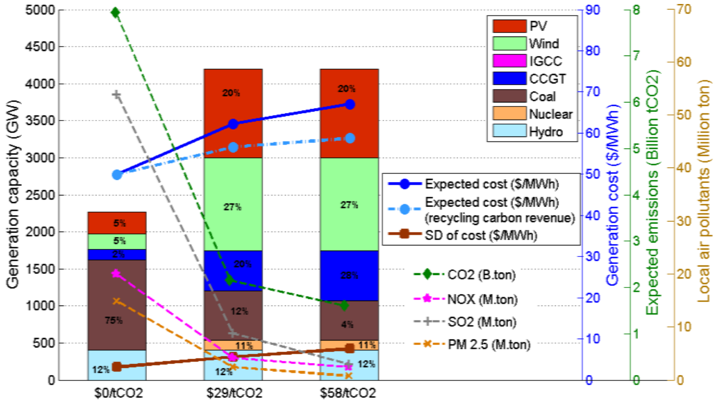

Fig. 2. The least cost generation portfolios for different carbon prices. Percentages indicate the share of annual generation from that technology.

The results suggest that without carbon pricing mechanisms, there is a relatively low incentive to invest in renewable technologies, and hence coal will continue to be the main generation source resulting in high emissions. However, a relatively modest carbon price of $29/tCO_2$ can lead to considerable increase in renewables and reduction in coal-fired generation, and hence emissions. The total installed capacity required in the cases with a carbon price is significantly higher than the case without a carbon price due to the amount of PV and wind capacity required given their low capacity factors. Although the scenario without a carbon price has the lowest cost and cost risk (SD of cost), the CO_2 emissions and local air pollutants are significantly higher than the scenarios with a carbon price. When carbon revenue is recycled, the cost difference in the least cost portfolio between the zero and $29/tCO_2$ carbon price sensitivity is around $7/MWh (or 10%) while the difference in CO_2 emissions can be as high as 6 $BtCO_2$ (or 80%).

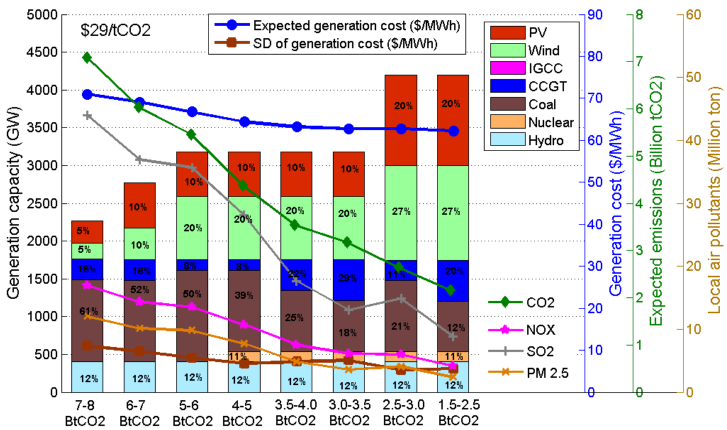

Fig. 3. The least cost generation portfolios for each emission range

The lowest cost options for achieving certain CO_2 emission targets can be identified according to Fig. 2, which shows the least cost generation portfolios for each emission range. The figure illustrates that the portfolio with the lowest renewable penetration level (i.e. 20%) not only has the highest emissions level, but also the highest cost and cost risk. This portfolio consists mainly of coal-fired generation and relatively moderate amount of gas-fired generation. On the other hand, the least cost portfolio in the lowest emissions range (1.5-2.5 $BtCO_2$) has the lowest industry cost and cost risk. The lowest cost option in maintaining the current emissions level, which is around 4 $BtCO_2$, while meeting the electricity demand growth in 2030 involves generation portfolios which compose of around 40% renewables (i.e. portfolio in the range 3.5-4.0 and 4-5 $BtCO_2$). However, higher renewable penetration would be required if China is to achieve its ambitious emission reduction targets. For example, in order to achieve emissions targets in the range 1.5 – 2.5 $BtCO_2$ in 2030, the lowest cost option is to source around 60% of energy from renewables and only 10% from coal-fired generation. The results also suggest that nuclear and CCGT also play a key role in low-carbon electricity generation portfolios, providing around 10% and 20% of total annual energy respectively.

Conclusions

- Utility-scale wind and PV generation have been shown to play a key role in minimising future industry costs, cost risks and emissions. Renewable penetration of around 40%-60% appears to be the most efficient in 2030. Gas-fired and nuclear generation will also play a valuable in supporting renewables by providing peaking, intermediate and baseload capacity. There appears to be little incentives to invest in new coal-fired generation due to its high capital and environmental costs unless the gas price is extremely high.
- With a relatively modest carbon price, it is possible to achieve emission reductions outcomes in a cost-effective manner through increased investment in large-scale renewables. The modelling results provide key energy and climate policy implications for China's electricity sector, particularly with regard to the future role of conventional and renewable generation, future carbon prices.

References

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[2] P. Vithayasrichareon and I. F. MacGill, "A Monte Carlo based decision-support tool for assessing generation portfolios in future carbon constrained electricity industries," *Energy Policy*, vol. 41, pp. 374-392, 2012.