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Electric vehicles and large-scale integration of wind power – The case of Inner Mongolia in China

Wen Liu [a,*], Weihao Hu [b], Henrik Lund [a], Zhe Chen [b]

[a] Department of Development and Planning, Aalborg University, Denmark
[b] Department of Energy Technology, Aalborg University, Denmark

HIGHLIGHTS

- Quantify the extent to which electric vehicle can further the renewable energy integration.
- Electric vehicle can increase wind power integration by 8% in the case of Inner Mongolia.
- Mutual benefits have achieved between energy system and transport.
- Some negative consequences are caused when applying fuel cell vehicle.

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ABSTRACT

Renewable energy is one of the possible solutions when addressing climate change. Today, large-scale renewable energy integration needs to include the experience to balance the discrepancy between electricity demand and supply. The electrification of transportation may have the potential to deal with this imbalance and to reduce its high dependence on oil production. For this reason, it is interesting to analyse the extent to which transport electrification can further the renewable energy integration. This paper quantifies this issue in Inner Mongolia, where the share of wind power in the electricity supply was 6.5% in 2009 and which has the plan to develop large-scale wind power. The results show that electric vehicles (EVs) have the ability to balance the electricity demand and supply and to further the wind power integration. In the best case, the energy system with EV can increase wind power integration by 8%. The application of EVs benefits from saving both energy system cost and fuel cost. However, the negative consequences of decreasing energy system efficiency and increasing the CO_2 emission should be noted when applying the hydrogen fuel cell vehicle (HFCV). The results also indicate that developing renewable energy is crucial for transportation electrification.

1. Introduction

The increasing global concerns on climate change and energy security are forcing China to change its coal-dominated energy structure. Energy conservation, efficiency improvement and replacing fossil fuel with renewable energy are three crucial strategies which may help China to achieve sustainable energy development [1]. China has gained achievements by implementing those three strategies in the 11th Five-Year Period (2005–2010). The energy intensity (energy demand per gross domestic production (GDP)) decreased 20% from 2005 to 2010. This is mainly due to the activities launched to eliminate the backward production capacities in the industry sector [2]. The increasing penetration of combined heat and power (CHP) plants in the heating region of northern China contributed to the energy efficiency improvement [3]. Moreover, renewable energy has witnessed a rapid development, particularly the installed wind power capacity which has doubled every year since 2005 [4]. In most Chinese energy plans, more effort was traditionally put into the electricity and industry sectors considering their major contributions to the energy demand [5,6]. However, transportation is gaining increasing attention today due to its high dependence on oil production and the increasing potential of vehicle demand in the future [7].

The Inner Mongolia Autonomous Region (IMAR) is one of the frontrunners in China in terms of implementing those three strategies. Inner Mongolia had eliminated large backward production capacities in the industry sector by 2010 which successfully curbed the high growth rate of its electricity demand [8,9]. The share of CHP plants in the thermal power capacity increased from 8% in 2006 to 31.48% in 2010 [10]. Moreover, the wind power in Inner

* Corresponding author. Address: Vestre Havnepromenade 9, Room 2.411, 3rd floor, 9000 Aalborg, Denmark. Tel.: +45 9940 3670; fax: +45 9815 3788.
E-mail address: wen@plan.aau.dk (W. Liu).

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Mongolia has been experiencing a vast increase and installed wind power capacity approached 10.9 GW in 2010 and the share of wind power in the electricity supply was about 6.5% in 2009 [10]. However, the slowed growth rate of the electricity demand, the increased share of CHP plants and the constant leap-forward development of wind power have led to two major problems in the Inner Mongolian energy system: (1) the challenge of unbalance between electricity demand and supply became worse. The excess electricity increased and most of it was produced in the heating period (begins 15th of October and ends 15th of April) when the CHP had to be fully operated to satisfy the heat demand, (2) many wind turbines were shut down when the excess electricity occurred and as the coal-dominated energy supply system was rigid, part of the coal-fired power plants had to operate continuously in order to secure the grid stabilization. Abandoning wind power generation in Inner Mongolia caused large economic losses amounting to more than one billion Chinese Yuan (158 million US dollar) in 2010 [11].

These problems will become more severe considering the fact that wind power and CHP are both expected to expand in the coming decades. China has approved the plan of developing seven ten-GW wind power bases by 2020 [12], of which four wind power bases are located in the neighbouring provinces of Inner Mongolia (see Fig. 1). The target of wind power capacity in Inner Mongolia is 50GW by 2020 which is about five times as much as in 2010. In these circumstances, the ability of the Inner Mongolian energy system to integrate more fluctuating wind power needs to be improved rather than highly relying on the continuous construction of long-distance transmission lines. The neighbouring provinces are more or less undergoing the same problem or probably will so in the future. Inner Mongolia is a unique region in China because it owns the richest reserve of coal resources and the most abundant wind power resources in the country. The challenges and opportunities of developing wind power in Inner Mongolia are both distinct. The experience of integrating renewable energy and rearranging the coal-dominated energy structure is worth learning for the other regions in China. Fig. 1 shows the geographic location of Inner Mongolia, the wind power distribution in China and the development targets of seven wind power bases by 2020.

Diversified studies have been carried out in order to address the technical issue of integrating more fluctuating renewable energy. Focuses are from more reliable methods of forecasting wind power [13], controllable loads such as hot water heating [14] and heat pumps [15]. Transport electrification shows the potential to connect transport to the rest of the energy system. With the ability to consume electricity from the public grid, electric vehicles (EVs) may serve as one of the solutions to smooth the discrepancy between the electricity supply and demand and to further the renewable energy integration. Much research have been investigated to detail the impacts of EVs on the power system, such as the impact on the regional power generation [16,17], the power system operation [18,19] and the distribution network [20,21].

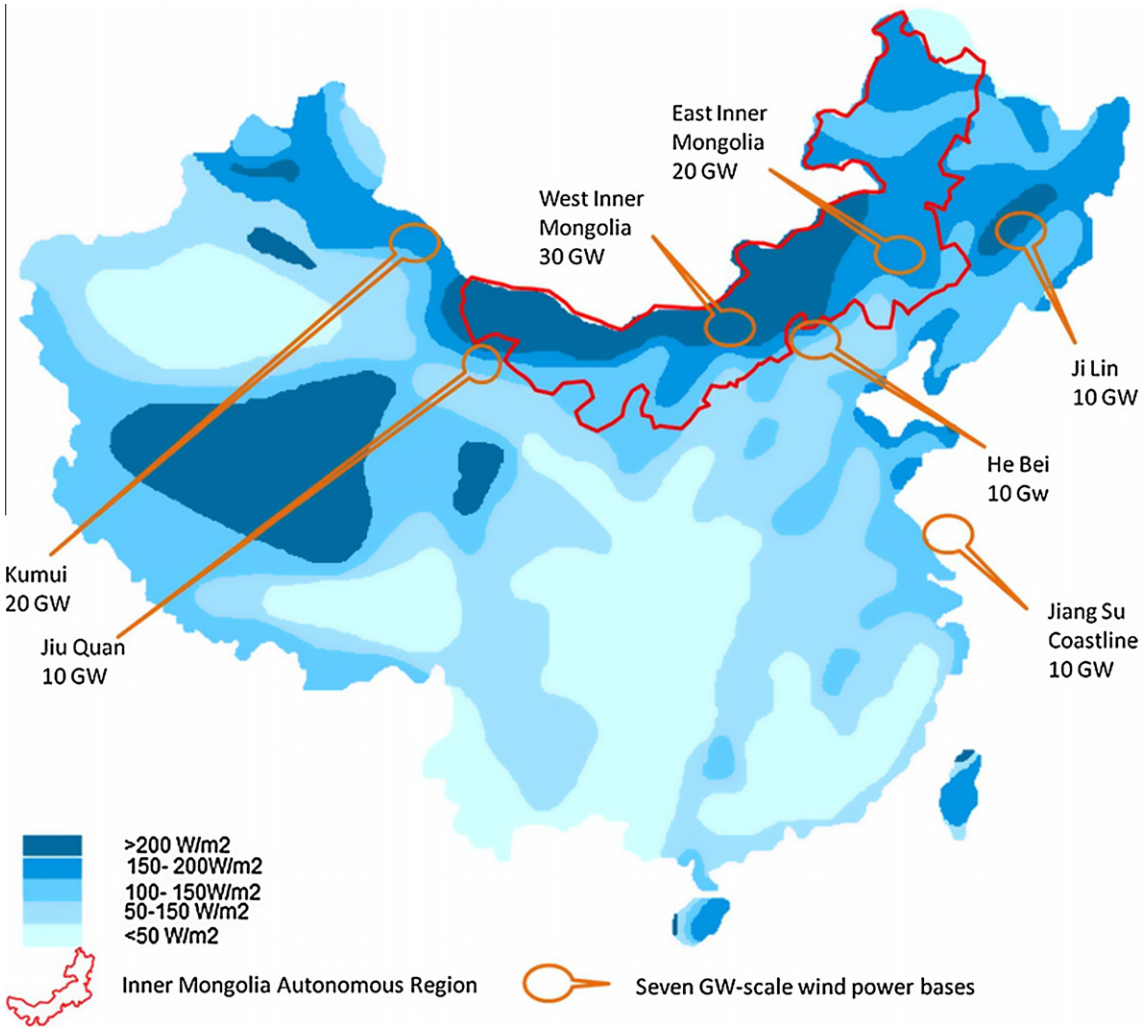

Fig. 1. The geographic location of Inner Mongolia, wind power distribution in China and seven wind power bases by 2020.