https://doi.org/10.1016/j.enpol.2020.111758

Low or No Subsidy? Proposing a Regional Power Grid Based Wind Power Feed-in Tariff Benchmark Price Mechanism in China

Ruixiaoxiao Zhang[a,b], Koji Shimada[c,d*], Meng Ni[a,b*], Geoffrey Q.P. Shen[a,b], Johnny K.W. Wong[e]

[a] Ng Wing Hong Laboratory for Sustainable City, Department of Building and Real Estate, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, China
[b] Department of Building and Real Estate, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, China.
[c] Department of Economics, Ritsumeikan University, Shiga, Japan.
[d] Research Organization of Social Science (BKC)
[e] School of Built Environment, Faculty of Design, Architecture and Building, University of Technology Sydney, Australia

Abstract

The Chinese government plans to adopt a low or no subsidy policy mechanism on renewable energy power development in the future. To achieve a balance between reducing financial burden on the government and ensuring profitability of investors as well as to account for the regional differences in China, a novel regional wind power grid feed-in tariff benchmark price mechanism by Net Present Value (NPV) method and Real Option (RO) method is proposed in this paper. The results voice support on the appropriateness of gradually decreasing the wind feed-in tariff (FIT) benchmark price to as low as the coal-fired FIT. The proposed FIT price level is presented as a price range on the basis of a guaranteed Internal Rate of Return (IRR) falls in between 8% to 15% for wind power investors. The results indicate that the current FIT price should be readjusted and redistributed. Although the FIT price in Central and South China grids is recommended to be relatively high, the NPV of wind farm project value in six regional grids are at the same level.

---

* Corresponding authors: Koji Shimada; Meng Ni
Email: shimada@ec.ritsumei.ac.jp (Koji); meng.ni@polyu.edu.hk (Meng)
Tel: +81 77 561 5183 (Koji); +852 2766 4152 (Meng)

Keywords

Feed-in Tariff; Net Present Value; Real Option; Regional Power Grids.

1. Introduction

In January 2019, the National Development and Reform Committee (NDRC) stipulated the *Notice on work related to wind power and photovoltaic power generation connected to grid without subsidy* (NDRC, 2019a). The attempt of the *Notice* expresses the government's intention to promote a low or no subsidy policy mechanism on renewable energy power development in the future. The reform of the wind FIT benchmark price in China has been concerned by the government for a long time. The highest administrative organ NDRC has promulgated a series of notices including the notices related to consecutive adjustment on wind FIT benchmark price level and executing nationwide carbon emission trading scheme (NDRC, 2019b, 2017a, 2017b, 2016a, 2015a, 2015b, 2014, 2011, 2009a), in order to promote the prosperous wind power development in China to achieve a sustainable environment. As sub-ordinary bodies of NDRC, the National Energy Administration (NEA) and the Ministry of Finance (MF) has also stipulated affiliated policies (MF, 2015; NEA, 2013) to assist in encouraging wind farm construction projects.

In recent years, some researchers around the world have proposed new price policy mechanisms to adjust the renewable energy FIT price level. Yang and Ge (2018) introduced a dynamic distributed solar power FIT pricing model that considered the unit generation cost, profit and tax. The results suggested a 5-tier incentive mechanism based on the irradiation time from 0.3245-1.0708 CNY/kWh in 2017, to 0.2159-0.7125 CNY/kWh in 2020. Barbosa et al. (2018b) applied the NPV and real option method to identify the fixed or unfixed minimum price guarantee with regulatory uncertainty. Their study pointed out that a fixed FIT could induce the investment even the price was lower than market price because it provided a risk-free environment. Antweiler (2017b) employed a methodology which combines FIT and capacity-augmentation-tariff to analyse the optimal price mechanism on wind and solar energy. His study recommended that the price differentiation mechanism was economically meaningful according to different types and locations of wind farms. Devine, Farrell, and Lee (2017a) applied a risk aversion model to simulate the optimal FIT mechanism from investors' and policymakers' perspectives, and concluded that the flat-rate FIT and premium FIT were optimised in different risk-aversion situations. Kim and Lee (2012a) employed NPV method to optimize four FIT payoff structures for solar power generation and added in economic constraints to develop an option-like featured model.

The policy reform is imperative. Different from previous studies, this study has proposed a brand-new FIT policy mechanism – Regional-power-grids-based FIT policy mechanism, which is the continuity of the authors' preliminary research (Zhang et al., 2019a). The contribution of this study is twofold. Firstly, this study advocates a reform of wind power FIT policy mechanism from current one to a novel one. The current one refers to a four-wind-resource-area-based wind power FIT policy mechanism, which has classified 31 provinces, municipalities and autonomous regions into four wind resource categories (Table.A.1) in accordance to annual average effective wind energy density and cumulative hours of wind speed of 3-20 m/s (Table A.2). The historical wind power FIT benchmark prices set by the Chinese government are distinguished in four wind resource areas (Table.A.3), where higher prices are distributed to areas with less wind resource abundancy in order to encourage the investment in those areas in particular. With the support of FIT policy, the development of wind power is drastic and status quo of current wind power installed capacity is demonstrated in Fig.A.1. The novel one that proposed by this study refers to a six-regional-power-grids-based wind power FIT policy mechanism (Fig.B.1)[1], which has considered the regional variation on accommodation ability of electricity consumption (reflected by wind power curtailment rate and wind farm operating hours), different regional development of carbon emission trading scheme (reflected by carbon emission factors and carbon trading prices), as well as regional FIT price deduction rate based on historical data. Secondly, the proposed policy mechanism has solved the rationality problem on lowering the wind power FIT benchmark price to a minimized level. The model that established by this study is based on strong theoretical support and empirical data. This study has applied the NPV method and the RO method to model the cash flow, project value and risks in enterprise's managerial flexibility and uncertainties during warranted life of a typical 45 MW wind farm which comprises of 18 units of 2,500 kW wind turbines. The feasibility of the methodology in renewable energy field could be proven by existing researches (Barbosa et al., 2018; Fagiani et al., 2013; Kim and Lee, 2012; Lin and Wesseh, 2013; Penizzotto et al., 2019; Rigter and Vidican, 2010; Ritzenhofen and Spinler, 2016; Schmidt et al., 2013; Wesseh and Lin, 2016; Yang and Ge, 2018; Zhang et al., 2016) . The result illustrates different wind power FIT benchmark price adjusting levels in different regionals, which has provided constructive prospectives and insights towards the future wind power market to policymakers and wind power investors.

Formatted: Highlight

Formatted: Highlight

---

[1] The basic information of six regional power grids is summarized in Table.B.1.

The structure of this paper is organized as the following: Methodology is presented in Section 2, Results and Discussions are conducted in Section 3, and Conclusion and Policy Implications are summarized in Section 4.

Formatted: Automatically adjust right indent when grid is defined, Space After: 8 pt, Adjust space between Latin and Asian text, Adjust space between Asian text and numbers

2. Methodology

Section 2.1 comprehensively introduces the concept of applying NPV method considering RO. The conventional NPV method only calculate the discounted cashflow subtracts the upfront investment cost, but in this paper, the value of RO which counts in the enterprise's managerial flexibility and uncertainty is also considered as a loss and subtracted from the discounted cash flow. The cashflow of a wind farm project comprises of the profit from selling on-grid wind power, the profit from carbon emission trading scheme, the profit from curtailed wind compensation, the expenditure on the operation and maintenance (O&M) cost and tax payment. Relevant policies which can support this paper's calculation are referenced in each sub-section. The principle of employing RO is explained in Section 2.2. the value of RO represents the risk of an enterprise's managerial flexibility and uncertainty to invest in the wind power project immediately instead of waiting or delaying.

2.1. Net Present Value Method

In this paper, NPV is calculated by means of Eq. (1) on the basis of the following equation:

$$V^{NPV} = \sum_{t=0}^{L} \frac{CF_t}{(1+r)^t} - RO - CI_t \tag{1}$$

Where

$$CF_t = ELE_t + CER_t + CUR_t - OMC_t - TAX_t \tag{2}$$

V^{NPV} stands for the amount of net presenet value, CF denots yearly cash flow of the project and CI represents capital investment. RO represents the enterprises' managerial flexibility and uncertainty investigated by~~, the value of RO is calculated by means of quantifying the systematic risk and idiosyncratic risk using~~ the Black-Scholes Model, which will be discussed in Section 2.2. The wind turbine life span is L and the investment is settled in yeat t. r denotes the discount rate. The calculation of yearly cash flow includes the profits from selling wind power to the grid ELE, the profits from carbon trading mechanism CER, the compensation on the curtailed wind power due to systematic failure CUR_t, the operation and maintenance cost OMC, as well as the tax expenditure TAX.

2.1.1. Profit from Selling Grid-Connected Wind Power

The profit for the wind farm investors on selling the wind power to the regional power grids is calculated by the following equations:

$$WF_t = \frac{H_i}{h} * 100\% \tag{3}$$

$$WF_{t+1} = WF_t * (1 - R_{dep}) \tag{4}$$

$$GE_t = P_t * N * WF_t \tag{5}$$

$$ELE_t = GE_t * FIT_t \tag{6}$$

$$FIT_{t+1} = FIT_t * e^{R_{fit}} \tag{7}$$

Where H_i stands for the annual wind farm utilised hour for grid-connected wind power generation, and h denotes the annually total hour. Wind farm capacity factor WF_t is calculated by H_i and h. GE_t denotes the grid-connected power that generated from wind energy, P_t denotes the rating power of a wind turbine system, R_{dep} denotes the wind turbine system depreciation rate. FIT_t stands for the feed-in-tariff price level at year t and it follows an exponential descending trend with rate value of R_{fit}. The decreasing rate R_{fit} is calculated according to the actual changing rate over the past years that stipulated by the NDRC.

~~Since the North China grid, Northeast China grid and Northwest China grid are facing a severe wind curtailment problem, the wind curtailment rates are getting even worse over the past three years (Zhang et al., 2019b).~~

2.1.2. Profit from Carbon Emission Trading Scheme

According to *BP Statistical Review of World Energy* (2017), the total carbon emissions in China at the end of 2017 was 9232.6 million tons, which accounts for 27.6% of world's output and is on the rise for consecutive years. Among all the power consuming segments, electricity and heat production contributes around 50% of the carbon emission, thus make carbon emission reduction a critical role of energy transition from traditional fuels to renewables. On December 19, 2017, the NDRC (NDRC, 2017b) promulgated *the Notice on the National Carbon Emission Trading Market Construction Plan (Power Generation Industry)*, which represents the start-up of nation-wide carbon trading system. The *Notice* stipulated more than 1700 enterprises (with a majority of power generation enterprises) should commit the obligation of carbon trading process. Therefore, the implementation of this policy will discourage the investor's choice on coal-fired power plants, but make the wind farm investment choice more attractive (Zhao et al., 2018). Therefore, the North China grid, Northeast China grid and Northwest China grid should consider this factor as a potential influence on the amount of coal consumption.

The profit of wind farms from trading carbon emission certificate (CER_t) is calculated in accordance with the NDRC's (NDRC, 2016b) standardized combined margin emission factor of a certain grid in year t ($EF_{grid,t}$):

$$CER_t = EF_{grid,t} * GE_t * P_{c,t} \tag{8}$$

$$EF_{grid,t} = W_{BM} * BM_{grid,t} + W_{OM} * OM_{grid,t} \tag{9}$$

The $EF_{grid,t}$ is calculated by the weighted average of the build margin emission factor ($BM_{grid,t}$) and operational emission factor ($OM_{grid,t}$), the values are summarised in Table 1. The operating margin is the emission factor of the thermal power plants and all plants serving the grid that cannot be characterized as "must run". The build margin is the emission factor of a group of recently built power plants. The weights are denoted by W_{BM} and W_{OM}, respectively (China Environmental United Certification Center (CEC), 2016; SecuritiesIndustrial, 2013). The methodology ACM002 referred to the Global Climate Change Research Institute of the Tsinghua University targets at large-scaled (installed capacity above 15MW) wind farm projects has stipulated the value of W_{BM} and W_{OM} as 0.25 and 0.75, respectively (Liu, 2012).

Table 1. Values of build margin emission factor ($BM_{grid,t}$) and operational emission factor ($OM_{grid,t}$) in six regional grids in China. It is noted that the values are updated by weighted average method to year 2014 (NDRC, 2016b).

	$BM_{grid,t}$	$OM_{grid,t}$	$EF_{grid,t}$
North China grid	1.0000	0.4506	0.58795
Northeast China grid	1.1171	0.4425	0.61115
Northwest China grid	0.9316	0.3467	0.492925
Central China grid	0.9229	0.3071	0.46105

East China Grid	0.8086	0.5483	0.613375
South China Grid	0.8676	0.3071	0.447225

$P_{c,t}$ represents the carbon price. The NDRC has issued the *Notice on Pilot Work on Carbon Emissions Trading* and announced seven pilot provinces and cities to launch the carbon trading scheme in October 2011 (NDRC, 2011). During the pilot operation, the carbon price is fluctuated between 5-50 RMB/tCO_2e (Boer de et al., 2017). In December 2017, the NDRC released *the National Carbon Emission Rights Trading Market Construction Plan* to open up the nation-wide carbon trading mechanism and will be practised in 2019 (NDRC, 2017b). Therefore, referring to the historical data (Ministry of Industry and Information Technology, 2019), this study assumes 50 CNY/tCO_2e as carbon trading price in North, Northeast and Northwest power grids, and 30 CNY/tCO_2e in Central, East and South power grids.

Based on the previous research works (Brauneis et al., 2013; Fuss et al., 2009; Zhao et al., 2018; Zhu and Fan, 2011), $P_{c,t}$ follows a Geometric Brownian Motion (GBM) as:

$$\mathrm{dP}_{c,t} = \mu_c P_{c,t}\, dt + \sigma_c P_{c,t}\, dW_{c,t} \tag{10}$$

Where μ_c and σ_c denote percentage drift of carbon price and percentage volatility of carbon price, respectively. $W_{c,t}$ represents an incremental Wiener process and obeys normal distribution $W(t) \sim \mathrm{N}(0, \varepsilon_c^2 t)$, and ε_c denotes the parameter of the Wiener process.

2.1.3. Profit from Curtailed Wind Power Compensation

Refer to the overview of the status quo of the wind power development in China (Zhang et al., 2019b), the wind power curtailment rate is significant and the major reason is attributed to the inconsistency of power grid planning between power grid companies and local government. (Gu and Xie, 2014; Zhao et al., 2016a). Simply speaking, although the wind farms are constructed in areas with abundant wind resource (i.e., Northwest and Northeast China Grids), the population in these areas is not high, so the power demand is relatively low. It turns out that the wind power is unable to be fully accommodated by power consumers instantaneously, so that part of wind power has to be curtailed. As recorded, wind power curtailment problem appears to be severe in South, North, Northeast and Northwest China grids (Fig.C.1), which leads to a national average wind curtailment rate as high as 18% and 21% in year 2015 and 2016, respectively . Realized the urgent measure should be adopted to curb the wind power curtailment situation, the National Energy Bureau (NEB) has promulgated the *Notice on Wind Power Grid Connection and Consumption* to privilege the use of wind power in these regions. As a result, the national average wind curtailment rate has decreased heavily to 13.2% and 7% in year 2017 and 2018, respectively. Nevertheless, the wind power curtailment rates in Northeast and Northwest China grids are still high.

Formatted: Highlight

Formatted: Highlight

Formatted: Font: Italic

Due to the wind power curtailment problem, the wind power investors appear not to invest immediately but to wait-and-see. They are worried about their profit since the FIT is provided to "on-grid" wind power. Fortunately, In 2015, the NDRC has enacted the *Notice on Guaranteeing the Purchasing of Electricity Generated by Using Regenerable Energy Resources in Full Amount* (NDRC, 2015b), which stipulated that the amount of curtailed renewable power due to grid connection failure[2] or constrained dispatch quota could receive full compensation as the same rate of FIT price. This policy offsets the investment risk caused by

Formatted: Highlight

---

[2] Grid connection failure refers to some amount of the wind power has to be curtailed due to overcapacity, in order to prevent the power system from unstable frequency and other power safety problems (Liu and Zhang, 2018).

systematic failure[3] that should not be responsible by wind power investors, therefore, it encourages the wind power investors who is concerned about this issue to be more confident to enter the market. From 2015 on, the curtailed amount of wind power is required to be recorded in official document because of severe wind power curtailment situation emerged in China. North, Northeast, Northwest and South China grids are currently on record with curtailed amount of wind power, and this study has calculated the wind curtailment rate according to the official data and employed the value in the model to calculate the profit from curtailed wind power compensation:

$$CUR_t = \frac{R_{cur} * GE_t}{(1 - R_{cur})} * FIT_t \tag{11}$$

Where R_{cur} denotes the wind curtailment rate and CUR_t represents the profit from curtailed wind power compensation to the wind power investors.

2.1.4. Expenditure on O&M Cost and Tax Payment

In 2009, the Minister of Finance stipulated *the Notice on Value-added Tax Policy of Wind Power Generation*, which provided favourable tax preferential incentives for enterprise income tax (EIT_t) and value-added tax (VAT_t). The *Notice* announced that for wind energy project in China, the VAT_t has been deducted from 17% to 8.5% while the EIT_t has been exempted during the first three years, and then deducted from 33% to 15% during the second three years.

---

[3] Systematic failure refers to grid connection failure or constrained dispatch quota that is caused by the inconsistency of grid planning between power gird companies and local governments as aforementioned, that the corresponding curtailment problem should not be responsible by the wind power investor, so they are reasonable to receive the compensation.

$$OMC_t = (GE_t + \frac{R_{cur} * GE_t}{(1 - R_{cur})}) * UOMC_t * 10^3 \tag{12}$$

$$TAX_t = VAT_t + EIT_t \tag{13}$$

$$VAT_t = (ELE_t + CER_t + CUR_t) * R_{vat,t} \tag{14}$$

$$EIT_t = [(ELE_t + CER_t + CUR_t) * (1 - R_{VAT,t}) - OMC_t] * R_{EIT,t} \tag{15}$$

The expenditure on O&M cost is presented in Eq. (12), where $UOMC_t$ denotes the unit operation and maintenance cost. The expenditure on tax payment is calculated by Eq. (13) to Eq. (15), where the $R_{VAT,t}$ and $R_{EIT,t}$ denote the rates of value-added tax and enterprise income tax, respectively.

2.1.5. Investment Cost

The upfront investment cost is calculated as below:

$$CI_t = UC_t * P_t * N * 10^3 \tag{16}$$

$$\mathrm{d}UC_t = \mu_u UC_t \, dt + \sigma_u UC_t \, dW_{u,t} \tag{17}$$

Where UC_t represents the unit investment cost of investing a wind farm project. μ_u *and* σ_u denote percentage drift of unit investment cost and percentage volatility of unit investment cost, respectively. $W_{u,t}$ represents an incremental Wiener process and obeys normal distribution $W(t) \sim \mathrm{N}(0, \varepsilon_u^2 t)$, and ε_u denotes the parameter of the Wiener process. Eq. (17) demonstrate the GBM of the investment cost.

The value of the parameter in the model are summarized in Table 2.

Table 2. Parameters input in the NPV model.

Parameters	Description	Value	Unit	Source
r	Discount rate	0.049	Per year	(REUTERS, 2017)

L		Life span of a wind turbine	20	Years	/
h		Annually total hours	8760	Hours	(Cheng and Yu, 2013)
H	North	Average annually operating hours	2057	Hours	(Ministry of Industry and Information Technology, 2018)
	Northeast		2152		
	Northwest		1826		
	Central		2033		
	East		2325		
	South		2012		
P		Rated wind power capacity	45	MW	Assumed
N		Number of wind farms	1	/	Assumed
R_{cur}	North	Annually wind curtailment rate in severe areas	6.32	%	Calculated by this study
	Northeast		16.62		
	Northwest		16.40		
	South		2.67		
R_{dep}		Depreciation rate	0.025	Per year	(Ragheb, 2017)
R_{fit}	North	FIT reduction rate	-2.836	%	Calculated by this study
	Northeast, Northwest		-2.899		
	Central, East, South		-1.674		
$BM_{grid,t}$		Build margin emission factor of a certain grid in year t.	Refer to Table 1.	tCO_2e/MWh	(NDRC, 2016b)
$OM_{grid,t}$		Operational margin emission factor of a	Refer to Table 1.	tCO_2e/MWh	(NDRC, 2016b)

		certain grid in year t.			
W_{BM}		Weight of build margin emission factor	0.25	/	(Liu, 2012)
W_{OM}		Weight of operational margin emission factor	0.75	/	(Liu, 2012)
$P_{c,t}$	North, Northeast, Northwest,	Carbon trading price	50	CNY/tCO_2e	(Ministry of Industry and Information Technology, 2019)
	Central, East, South		30		
μ_c		Percentage drift of carbon price	0.03	Per year	(Zhang et al., 2016)
σ_c		Percentage volatility of carbon price	0.02	Per year	(Zhang et al., 2016)
UC_{t-1}		Unit investment cost	3650	RMB/kW	(Esmaieli and Ahmadian, 2018)
μ_u		Percentage drift of unit investment cost	-0.06	Per year	(Rigter and Vidican, 2010)
σ_u		Percentage volatility of unit investment cost	0.04	Per year	(Rigter and Vidican, 2010)
$UOMC_{t-1}$		Unit operation and maintenance cost	0.2	CNY/kWh	(Zhang et al., 2016)
$R_{VAT,t}$		Value-added tax rate	0.085	Per year	The *Notice*
$R_{EIT,t}$		Enterprise-income tax rate	0.25	Per year	(Li et al., 2013)

2.2. Real Option Method

Although the above NPV method is very useful to simulate the investment performance of large-scale wind power projects, the natural limitation of this method still exist (Pringles et al., 2015). The investment in secondary infrastructure is regarded merely reversible, so the investors are taking every step carefully to eliminate all potential risks. Therefore, in the China's market context, since it is acknowledged that the wind power FIT benchmark price descends annually and quickly, so the investors prefer to wait and observe or defer their investment rather than investing immediately. Hence, under a dynamic investing environment, the investors have the flexibility to take advantage of the "time" to make appropriate response until the investment uncertainty is well solved. Nevertheless, the value during the "time" is unable to be measured by NPV method (Liu and Ronn, 2020). Under this circumstance, the RO method is widely applied to address the corresponding problem, and the value refers to "an enterprise's managerial flexibility and uncertainty".

The RO method has been well applied in the research field of renewable energy policy design. For example, Davis and Owens (2003) focused on optimize the renewable energy research and development (R&D) funding level, and they used RO method to determine whether additional values will be created if R&D funding levels are varying. Kim et al. (2014) also focused on the R&D market in wind power, and applied RO method to measure the economic value of investing in wind power R&D projects. Gollier et al. (2005) employed RO method to compare the option value of managerial flexibility and uncertainty between a large-scale nuclear power plant with a small-scale one, and provided plant-size-related insights for decision making. The similar comparison studies on hydropower project and biomass power project are completed by Bøckman et al. (2008), Fleten et al. (2007) and Wang et al. (2014). Besides, RO method is also applied in investment evaluation, policy evaluation and pricing design by Lin and Wesseh (2013), Penizzotto et al. (2019), Ritzenhofen and Spinler (2016), Wesseh and Lin (2016), Yang and Ge (2018) and Zhang et al (2016) .

2.2.1. Black-Scholes Model

Black-Scholes Model (BSM) and Binomial Model (BM) are two popular models applied by researchers to solve the RO problems. The BSM requires five key inputs (underlying asset stock price and strike price, volatility, duration to the maturity of the option, and risk-free risk) into the model to determine the theoretical option value, whereas the BM starts from a stock price, and then produces a binomial tree with a up limit and a down limit by the volatility step by step till the time to expiration, and finally it requires a backward computation (Hoadley, 2020). This study chooses to use BSM to calculate the value of RO because of two reasons. Firstly, there are 1002 observations in this study, so the BSM is more efficient over the BM since it can reduce the computational complexity. Secondly, regarding the output result from the BSM model and BM model, Ahmad Dar and Anuradha (2018) have proved that the result does not show much of a difference. Therefore, considering the computational efficiency and accuracy, ~~This study has employed the Black-Scholes~~ this study employed the BMS model to calculate the value of RO. Numbers of researchers have taken advantages of the BSM model on financial and economic projects. Apart from the application in the renewable energy policy field that is mentioned before, the BSM model is also applied in predicting and measuring the stock price, bankruptcy risk and transaction cost (Al–Zhour et al., 2019; Chowdhury et al., 2020; Hsu and Wu, 2020), ~~based on the empirical practices by existing researchers. The meaning of RO is that it accounts for the enterprises' managerial flexibility and uncertainty, which is regarded as a stochastic loss added to the fixed upfront payment. The Black-Scholes model includes stochastic differential equations and requires fixed inputs to operate the model.~~ The theoretical function of the BSM is expressed as follows (Black and Scholes, 1973, 1972):

$$\mathrm{RO} = P_{asset}\, N(d_1) - P_{strike}\, e^{-R_f D_t}\, N(d_2) \tag{18}$$

Where RO denotes the value of the option, P_{asset} and P_{strike} represent the underlying asset price and strike price, respectively. R_f denotes the constant risk-free rate, which can be expressed by a 10-year China government bond yield of 3.19%. D_t denotes the duration to the maturity of the option. $N(d_1)$ and $N(d_2)$ stands for process of standardized cumulative density function. The estimation of $d_1$and d_2 can be expressed by the following equations:

$$d_1 = \frac{\ln\frac{P_{asset}}{P_{strike}} + \left(R_f + \frac{{\sigma_{asset}}^2}{2}\right) D_t}{\sigma_{asset}\sqrt{D_t}} \tag{19}$$

$$d_2 = d_1 - \sigma_{asset}\sqrt{D_t} \tag{20}$$

Where ${\sigma_{asset}}^2$ denotes the annual volatility of underlying asset.

~~2.2.~~ 2.2.2. *N-Asset* Portfolio Combination

Formatted: Font: (Default) Cambria, 14 pt, Bold

Formatted: Normal, No bullets or numbering

This study established a portfolio containing 10 sets of stocks in different wind power industries, among which a half are wind power generators and another half are wind turbine manufacturers. These10 enterprises are selected due to their top rankings in terms of the market share in wind power industry, and in addition they are listed companies in

Mainland China or Hong Kong, so the datasets of their historical daily stock return could be collected online for further calculation and estimation, which is a very important procedure and a significant advantage of the variance-covariance approach as stated above. Table. ~~A~~D.1 presents the full name, stock codes of the 10 enterprises and the observation of daily stock return in calculation. Table. ~~A~~D.2 summarizes the descriptive statistics of the 10 stock datasets. Each set of the observed data falls within or around an absolute value of 0 of skewness and 3 of kurtosis, and the probability of Jarque-Bera test suggests to accept the null hypothesis of normal distribution (Soberón and Stute, 2017).

The portfolio combination plays a crucial role in determining the option value, because other input parameters such as duration to maturity and risk-free interest are fixed and constant. The value of underlying asset price, strike price and volatility are influenced by different portfolio combinations. In this study, we made a combination of different portfolio of N=2, 3, 4, 5, 6, 7, 8, respectively. The total number of observations is 1002.

The N-asset portfolio volatility is calculated by the following equation:

$$\sigma_{asset}{}^{2} = \sum_{i=1}^{N} \sum_{j=1}^{N} w_i w_j \sigma_i \sigma_j \rho_{(i,j)} \tag{21}$$

Where w denotes the weight of market capitalization of asset i and j in the combined portfolio, σ stands for the standard deviation of stock daily return of asset i and j and $\rho_{(i,j)}$ represents the covariance of stock daily return between asset i and j .

3. Results and Discussions

3.1. Overall Result

The comparison of wind power FIT benchmark price between government setting and suggested value by this paper is illustrated in Fig.1 The lower bound value and upper bound value represent the wind power FIT benchmark price level that ensures the enterprise’s internal rate of return (IRR) falls in between 8% and 15%. Fig.1 reveals that the current government setting value in Hebei and Inner Mongolia goes beyond the lower bound, whereas the current government setting value in Liaoning goes beyond the upper bound. This finding indicates that the current differentiate FIT price of Category I and Category II[4] is too low to attract investment in areas with abundant wind resource, which turns out a slowdown in wind farm investment in recent years and if the FIT price continues to be adjusted to a lower level by the government, consequently the stagnation in investment will emerge. On the contrast, the current government setting value in Liaoning is regarded too high, which will stimulate large amount of investment, and consequently turns out sever wind power overcapacity and curtailment problem.

Regarding other provinces, municipalities and autonomous regions, the current government setting value is considered in the safe zoon which guarantees IRR of 8% to 15% to investors. However, the current value in Gansu, Ningxia and Xinjiang is approximately near the lower bound. This finding provides the government a signal that the FIT benchmark price in these three regions should not be decreasing anymore. In addition, the differentiated FIT benchmark price in Category III[5] is also considered too low, thus the wind energy industry in areas with relatively abundant wind resource will foreseeably encounter many bottlenecks regarding further development. Although Jilin and

---

[4] ~~See Appendix. B~~
[5] ~~See Appendix. B~~

Heilongjiang are also classified into Category III, as they located in Northeast China grid where the suggested value by this paper is the lowest among six regional power grids, the current government setting value is in the middle level and indicates IRR of 11% to 12%. As for the provinces, municipalities and autonomous regions that locate in Category IV[6], the government setting value is found in the middle or higher level of the safe zoon. The IRR of enterprises under current FIT benchmark price is around 11% to 12% in Central and South China grid, and reaches 13% to 14% in North, Northwest and East China grid.

Fig.2 presents the suggested FIT benchmark price range in 2021 and 2022, under two possible scenarios regarding China's carbon trading market, respectively. Since China just opened the nationwide carbon trading market, the carbon trading price mechanism remains ambiguous. What is known is that marketization is the final goal and government regulation is the tool to adjust and intervene the market. Therefore, Scenario I demonstrates an increasing trend of carbon trading price in previous years by GBM. By contrast, Scenario II demonstrates a stable and constant carbon trading price. Compare Figs. 2(a), 2(b) with Figs. 2(c), 2(d), the suggested wind power FIT benchmark price in Scenario I is lower than that of Scenario II. It is because that the increased carbon trading price will offset more expenditure than a constant carbon trading price.

The total expenditure, total revenue and NPV of project value are illustrated in Figs.3-5, respectively. The NPV of project value is in the similar level of six regional power grids, that is because that this study uses one 45 MW typical wind farm as the model, so the

---

[6] ~~See Appendix. B~~

numbers of wind farms in each regional power grids are not counted. The average annual grid-connected wind power and polluting emission reduction is demonstrated in Fig.6.

Table 3 is the summary of the discussions in this section. It highlights the baseline of IRR, proposed FIT benchmark price in six regional power grids under two scenarios, number of households can be fed, policy implications to the government, the investment potential for the investors as well as the suitable enterprise type to launch the project. The following sections has explained the reason of setting the acceptable IRR in each regional power grid.

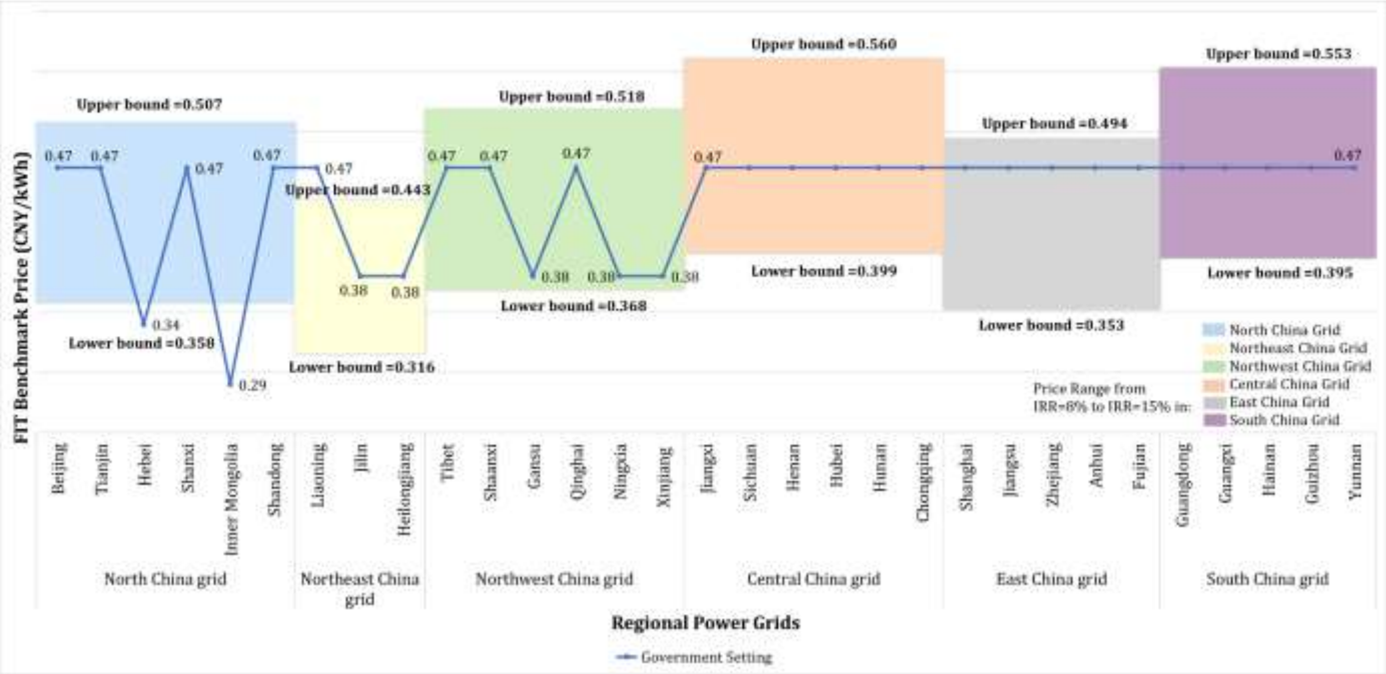
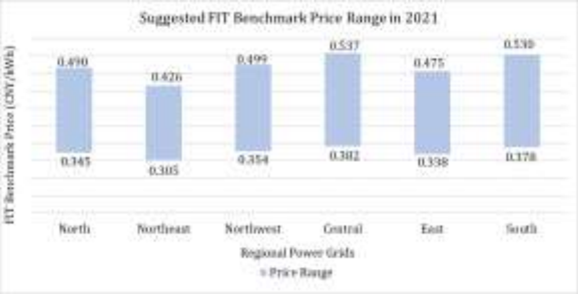


Fig.1 The comparison between the results and the current FIT price level.

<table>
<tr><td rowspan="2">Scenario I – Increasing Trend of Carbon Trading Price</td><td>

(a)</td></tr>
<tr><td>

(b)</td></tr>
<tr><td rowspan="2">Scenario II – Constant Carbon Trading Price</td><td>

(c)</td></tr>
<tr><td>

(d)</td></tr>
</table>

Fig.2 Suggested FIT price range in 2021 and 2022 under different scenarios.

3.2. North China Grid

The differences of current FIT benchmark price levels in Category I, II and IV are simultaneously reflected in North China grid, which result in severely unbalanced IRR for investors to invest in the same power grid. 21Century Economic Report (2010) has pointed out that the baseline of IRR which is acceptable by wind farm project investors in China is 8%. However, the wind power investors may reject to invest in Hebei and Inner Mongolia since their estimated IRR under the current FIT price are 7% and 5%, respectively, below the acceptable baseline. Moreover, since the discount rate for enterprises by the Central Bank of China is 4.9%, the wind power investors in Inner Mongolia is likely to face a losing proposition.

On the contrary, the current FIT benchmark price in Beijing, Tianjin, Shanxi, Shandong (included in Category IV) is more favorable by investors, since the IRR is estimated as 14%. It is suggested that the government could lower down the IRR standard in North China grid to a certain level of IRR equals 11% to 12% (Table 3). The saved financial budget from these four regions could be redistributed to investors in Hebei and Inner Mongolia.

3.3. Northeast China Grid

The suggested FIT benchmark price level by this paper in Northeast China grid is the lowest, with the price range falls in between 0.316 CNY/kWh and 0.443 CNY/kWh (Fig.1). This is because 19.3% of the nationwide wind power is generated by Northeast China grid, but the curtailed wind power accounts for 40% of the nationwide due to grid connection failure or constrained dispatch quota. As mentioned before, the current FIT price in Liaoning is found too high as the IRR reaches 17%. Although it is favorable to investors, the negative impact will emerge if many investors are attracted to invest in Liaoning. Firstly, the overcapacity and wind power curtailment problem will be aggravated. The electricity consumption in Northeast China grid only accounts for 6% of the national total electricity consumption (National Bureau of Statistics, 2019), which means that the electricity demand in this grid is not high. Therefore, continuing to construct wind farm in Liaoning will aggravate the overcapacity and wind power curtailment problem. To solve this problem, the need of consistency in grid planning and wind power accommodation is highlighted by a group of researchers (Luo et al., 2016; Shen and Luo, 2015; Si et al., 2011; Wang, 2010; Wei et al., 2018; Yin et al., 2017; Zhao et al., 2016a, 2016b). Secondly, unnecessary government expense will be triggered. The increase of the wind farm project in Liaoning will make the government compensate more on the curtailed wind power, which is a waste of government budget that can be avoided by lowering down the FIT benchmark price of Liaoning. Since the IRR in Jilin and Heilongjiang under current FIT price is 12%. The suggested FIT price in Liaoning should be at the same level as other two provinces, Jilin and Heilongjiang, of 0.38 CNY/kWh in 2020. Furthermore, considering the low electricity demand and severe wind power curtailment in Northeast China grid, it is recommended that the IRR baseline is acceptable between 9% and 10% (Table 3).

3.4. Northwest China Grid

There are six provinces and autonomous regions in Northwest China grid under Category III and IV, respectively. The current FIT benchmark price level could satisfy an IRR of 9% in Gansu, Ningxia and Xinjiang, and IRR of 13% in Tibet, Shaanxi and Qinghai. Northwest is facing the similar circumstance as Northeast that the electricity demand is relatively low. The electricity consumption in Northwest China grid accounts for 10% of the national total electricity consumption (National Bureau of Statistics, 2019), whereas the share of the wind power installed capacity accounts for 27% of the national total amount (Fig.7). Consequently, the curtailed wind power accounts for 37% of the national total amount. Therefore, this study suggests the government also lower down the FIT benchmark price in Tibet, Shaanxi and Qinghai, to the same price of that in Gansu, Ningxia and Xinjiang (0.38CNY/kWh) in 2020. Furthermore, the IRR baseline is recommended to set between 9% and 10% in Northwest China grid (Table 3).

3.5. Central and South China Grids

The statistics and results in Central China grid and South China grid are very similar, so the implications and reflections are interpreted simultaneously in one section. Fig.1 indicates that the current FIT level guarantees an IRR of 12% in both Central China grid and South China grid in 2020. The suggested lower bound value and upper bound value in these two grids are the highest among six regional power grids. In addition, both the total expenditure and total revenue (Figs.3-4) in these two grids are the lowest. It is because the wind farm average annually operating hours in these two grids are relatively low, which are just more than the Northwest China grid, so the amount of grid-connected wind power in these two grids are relatively low. In consequence, the profit from carbon trading mechanism and selling electricity to the grid is low.

As the installed wind power capacity could be almost fully adopted in the power gird, the government should keep encouraging investors to construct wind farms in these two areas, whereas avoid excessive expansion. Therefore, it is suggested that the FIT benchmark price levels in Central and South China grids better remain with the baseline of IRR at 12% to 13% (Table 3).

3.6. East China Grid

The current FIT price in East China grid indicate an IRR of 14% for investors, which appears to be the most profitable area for constructing wind farms. However, it is surprising to find that the suggested FIT benchmark price in East China grid is even lower than North and Norwest China grids, that the upper bound is eve lower than 0.5 CNY/kWh. This indicates that the profitability in East China grid does not solely depend on the price level of FIT, but also depends on the carbon trading mechanism as explained in the last section.

This study shows that the investment potential in East China grid is enormous, since the electricity consumption only in East China grid accounts for as much as 26% of the national total consumption. Nevertheless, the cumulative wind power installed capacity merely accounts for 7% (Fig.7) and the curtailed wind power is zero. This implies that the high electricity demand in East China grid highly improves the harvest of wind power, thus, this study ascertains that the baseline of future IRR for enterprises to invest should fall in between 13% and 14% (Table 3).

Table 3. Summary of the discussions.

		North China Grid	Northeast China Grid	Northwest China Grid	Central China Grid	East China Grid	South China Grid
IRR Range		11% to 12%	9% to 10%	9% to 10%	12% to 13%	13% to 14%	12% to 13%
Suggested FIT (Scenario I, unit : CNY/kWh)	Year 2021	0.390 to 0.420	0.315 to 0.332	0.368 to 0.388	0.466 to 0.489	0.431 to 0.451	0.460 to 0.483
	Year 2022	0.389 to 0.408	0.308 to 0.323	0.360 to 0.378	0.454 to 0.478	0.421 to 0.440	0.449 to 0.472
Suggested FIT (Scenario II, unit: CNY/kWh)	Year 2021	0.408 to 0.429	0.322 to 0.340	0.376 to 0.398	0.476 to0.499	0.440 to 0.461	0.470 to 0.493
	Year 2022	0.395 to 0.416	0.315 to 0.331	0.366 to 0.385	0.459 to0.481	0.425 to 0.445	0.453 to 0.475
Annually average on-grid wind power generation of a 45MW wind farm (unit: MWh)		71,716	75,028	63,662	70,879	81,059	70,147
Number of households can be fed[7]	Two-people family	58,706	61,418	52,114	58,021	66,355	57,422
	Three-people family	39,138	40,945	34,742	38,681	44,237	38,481
Reduced carbon emission ($MtCO_2e$)		45.00	54.99	37.54	32.68	49.72	32.23
Policy implications to government		FIT price in Hebei and Inner Mongolia should be raised	Consider the overcapacity and wind curtailment problem in Liaoning	Inhibiting the investment in Tibet, Shaanxi and Qinghai	The expenditure and the total revenue are the least	Profitability depend on both FIT price level and carbon trading mechanism	The expenditure and the total revenue are low
Investment potential for investors		Moderate	Low	Low	High	Enormous	High
Suitable Enterprise type		Medium-scale	Large-scale	Medium-scale	Small-scale	Large-scale	Small-scale

---

[7] According to China Statistical Yearbook 2018 (National Bureau of Statistics, 2019), the annual per capita electricity consumption is 610.8 kWh.

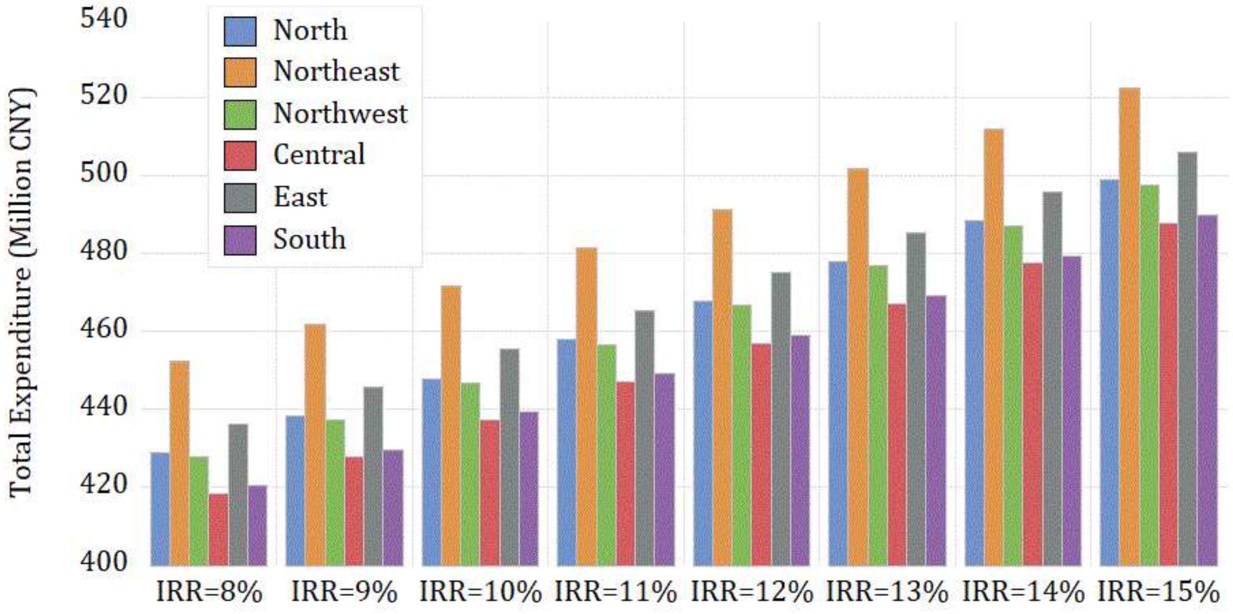


Fig.3 Estimated total expenditure under different value of IRR

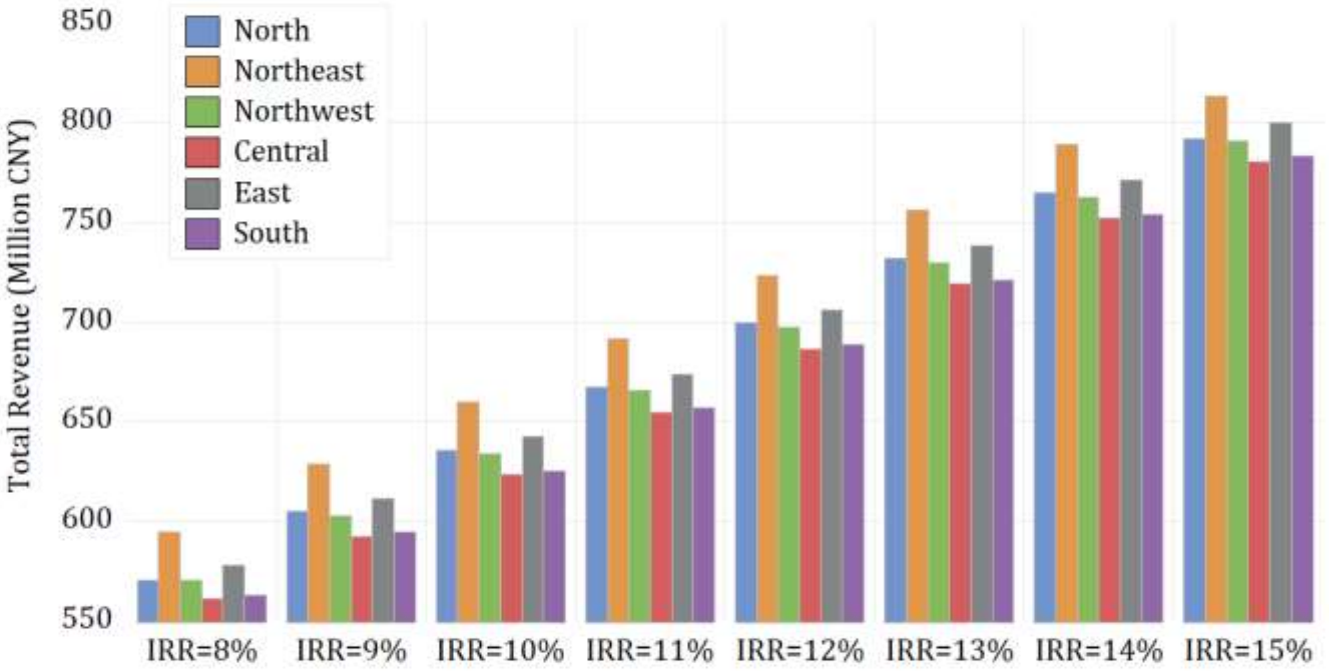


Fig.4 Estimated total revenue under different value of IRR

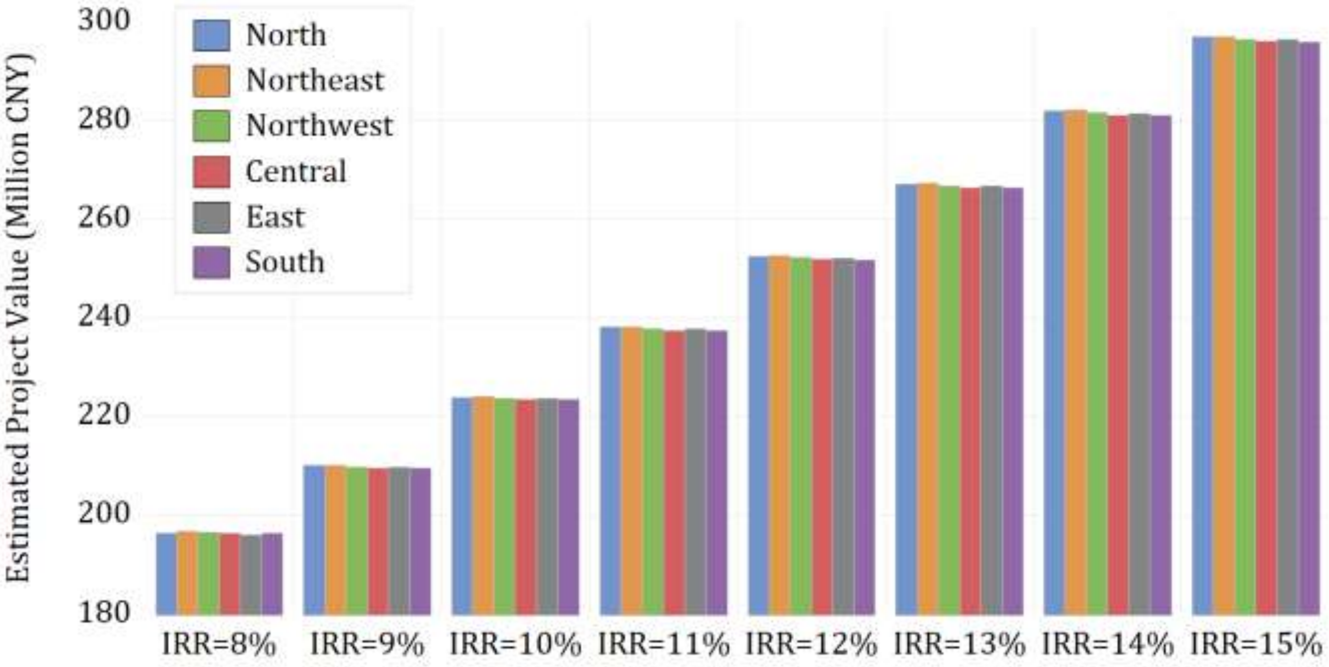
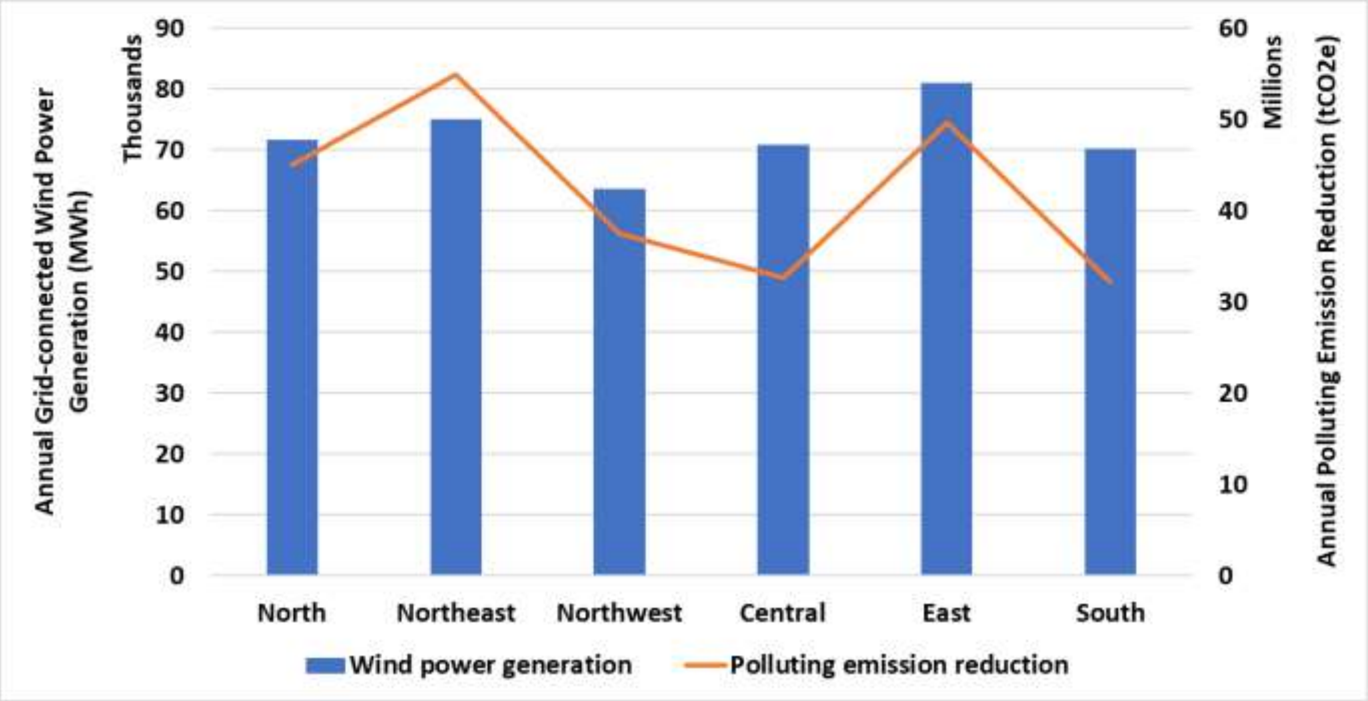


Fig.5 Estimated NPV of wind farm project value under different value of IRR



c

Fig.6 Estimated annual grid-connected wind power generation and polluting emission reduction

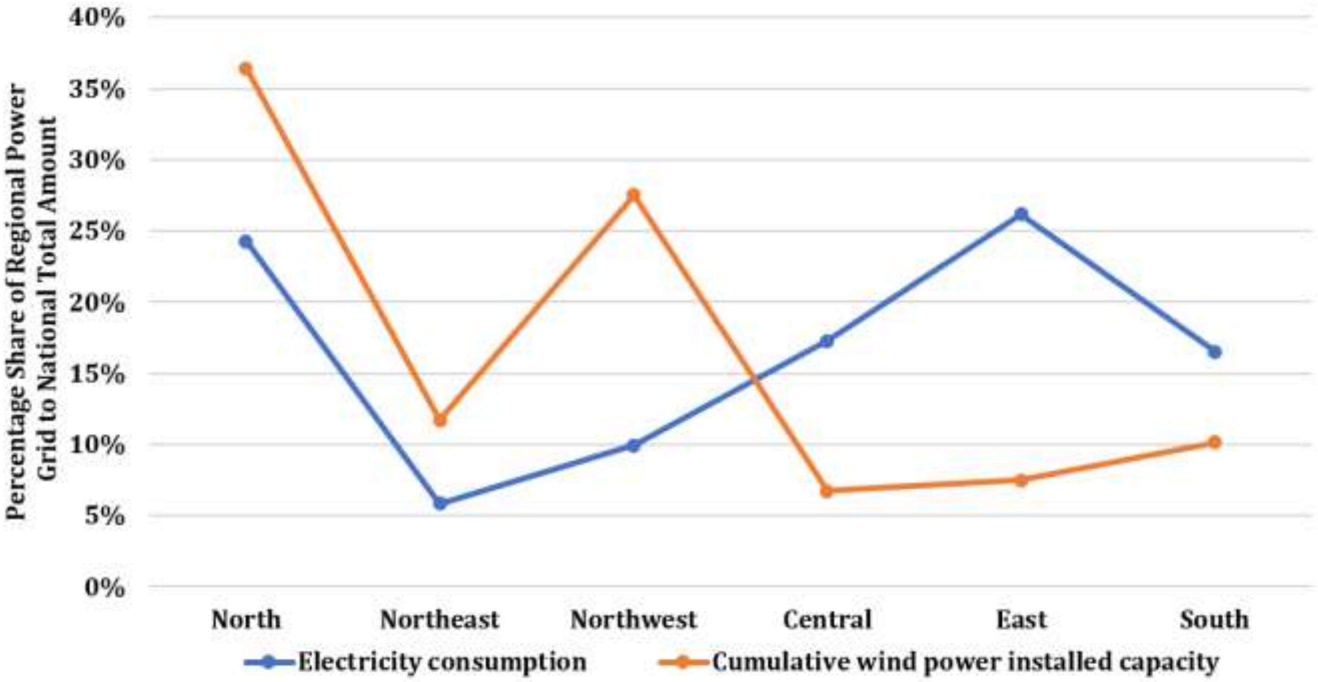


Fig.7 Percentage share of regional electricity consumption and cumulative wind power installed capacity to national total amount.

4. Conclusion and Policy Implications

This study has proposed a new wind power FIT benchmark price mechanism by applying the NPV method and RO method to optimize the FIT price in accordance to a baseline of IRR for enterprises fall in between 8% to 15%. The new wind power FIT benchmark price mechanism refers to a differentiated benchmark price mechanism based on six regional power grids in China, which is strongly recommended to substitute the current category-based mechanism. The NPV is calculated based on the cash flow of profit from selling electricity to the power grids, profit from receiving compensation due to systematic failure that should not be held accountable by wind farm investors, profit from participating in carbon trading certification mechanism, expenditure on operation and maintenance cost, as well as expenditure on tax payment. The RO method is employed to calculate the enterprises' managerial flexibility and uncertainty, which is regarded as a stochastic loss added to the fixed upfront payment. The RO method synthesizes the market capitalization and stock daily return of five leading wind farm manufacturers and five leading domestic wind power generators in China, and then produces 1002 asset portfolios by simulating all possible combinations among these ten enterprises. The value of RO represents the risks related to enterprises' right to postpone the investment. The results are comprehensively interpreted in Section 3,

This study contributes to the realignment of regional wind power FIT benchmark price level, which provides insights regarding the *Notice on work related to wind power and photovoltaic power generation connected to grid without subsidy*. The policy implications are summarized as follows:

(1) The open of China's nationwide carbon trading scheme and the implementation of renewable energy compensation are considered in the model. Whether the carbon trading mechanism is operated under a relatively liberalized electricity market (Scenario I) or under government's strict regulation (Scenario II), the proposed wind power FIT benchmark price level has provided the policymaker some comprehensive and systematic foresights by categorizing the IRR in different regional power grids.

(2) The risks and concerns of low IRR by the investors are eliminated and the investors are released from struggling against their social accountability by the RPS scheme and uncertainties brought by the systematic fault.

(3) According to the sensitivity analysis (Appendix. ~~C~~E), the most sensitive parameters in the model are the upfront cost and the grid-connect wind power generation. Therefore, improving technological development and restructuring grid planning to decrease the upfront cost or alleviate wind curtailment problem are the most efficient way to improve the investment environment.

(4) The redistribution of FIT subsidies is recommended. The proposed wind power FIT benchmark price level has reached a balance of regional differences, so the current FIT price should be realigned and redistributed.

(5) The estimated Levelized Cost of Electricity (LCOE) of wind power in different regional power grids (Appendix. ~~D~~F) indicates that the wind power production in East China grid is the most cost-effective, whereas in Northwest is the least cost-effective. Therefore, stimulating or inhibiting the investment in different regional power grids should be adjusted.

Acknowledgement:

Ms Zhang acknowledges the PhD studentship offered by the **Ng Wing Hong Laboratory for Sustainable City, Department of Building and Real Estate, the Hong Kong Polytechnic University.** Ms Zhang also acknowledges the Attachment Program supported by The Hong Kong Polytechnic University and **Research Organization of Social Science (BKC), Ritsumeikan University, Japan.**

Appendix. ~~B~~A Classification of the Current Wind Power FIT Subsidy Categories.

Table.~~B~~A.1 Provinces/ Autonomous regions/ Municipalities included in four categories of wind resources (NDRC).

Administrative areas included (Hu et al., 2013)
Category I: Inner Mongolia autonomous region except: Chifeng, Tongliao, Xing'anmeng, Hulunbeier; **Xinjiang uygur autonomous region**: Urumqi, Yili, Karamay, Shihezi
Category II: Hebei province: Zhangjiakou, Chengde; **Inner Mongolia autonomous region:** Chifeng, Tongliao, Xing'anmeng, Hulunbeier; **Gansu province**: Zhangye, Jiayuguan, Jiuquan
Category III: Jilin province: Baicheng, Songyuan; **Heilongjiang province**: Jixi, Shuangyashan, Qitaihe, Suihua, Yichun, Daxinganling region, **Gansu province except:** Zhangye, Jiayuguan, Jiuquan, **Xinjiang autonomous region except**: Urumqi, Yili, Changji, Karamay, Shihezi, **Ningxia Hui autonomous region**
Category IV: Other parts of China not mentioned above

Table.~~B~~A.2 Classification of four wind resource areas

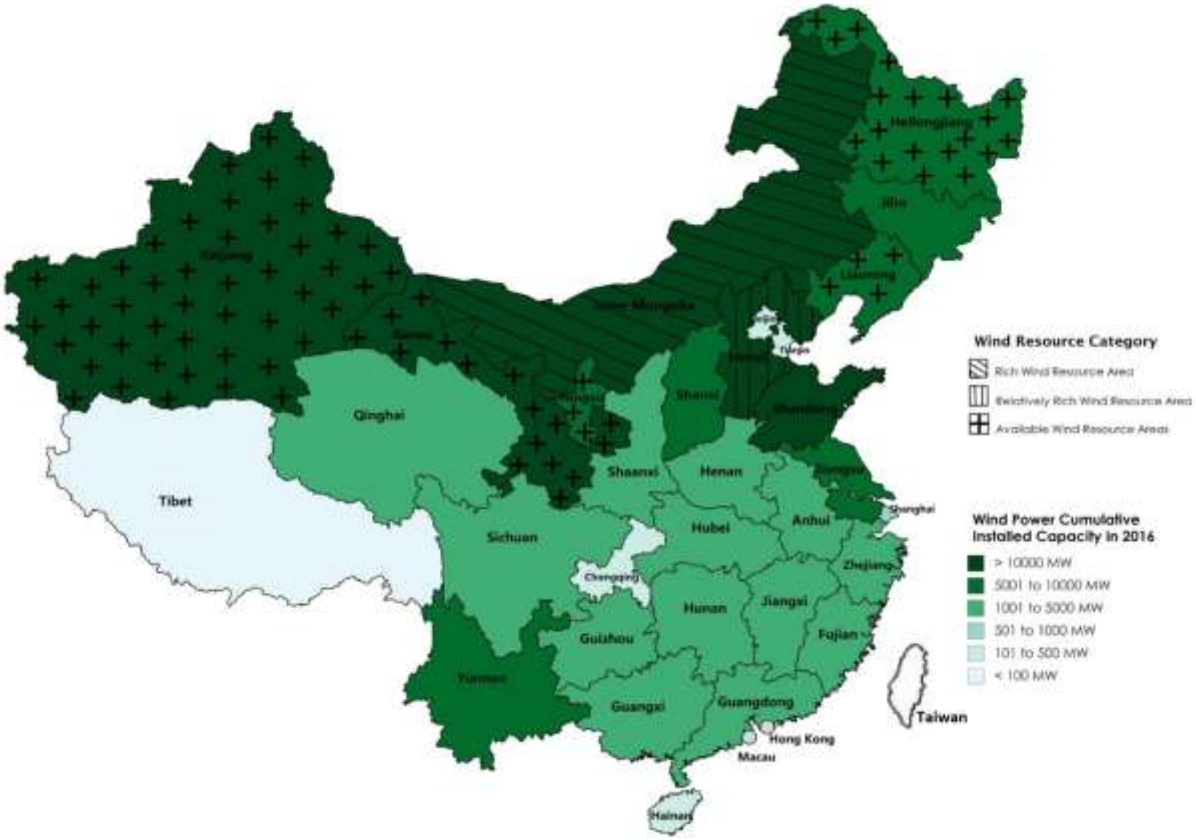
Category	Annual average effective wind energy density (D, W/m^2)	A~~a~~nnual cumulative hours (H) of wind speed of -3-20 m/s
I – Rich wind resource areas	D > 200	H > 5000
II – Relatively rich wind resource areas	150 < D < 200	3000 < H < 5000
III – Available wind resource areas	50 < D < 150	2000 < H 3000
IV – Poor wind resource areas	D < 50	H < 2000

Formatted Table

Table.A.3. Historical wind power FIT benchmark prices set by Chinese government (NDRC, 2019c, 2017a, 2016c, 2015c, 2014, 2009b).

Category	Before 2009	2009 to 2014	2015	2016	2017	2018	2019	2020
I	Desulfurized coal-fire power price + less than 0.25	0.51	0.49	0.47	0.44	0.40	0.34	0.29
II		0.54	0.52	0.50	0.47	0.45	0.39	0.34
III		0.58	0.56	0.54	0.51	0.49	0.43	0.38
IV		0.61	0.61	0.6	0.58	0.57	0.52	0.47

Fig.A.1. The situation of wind power installed capacity in different wind resource areas in China.



Formatted: Width: 27.94 cm, Height: 21.59 cm

Appendix B. Supplementary Materials on Six Regional Power Grids

Fig.B.1. The classification of regional power grids in China

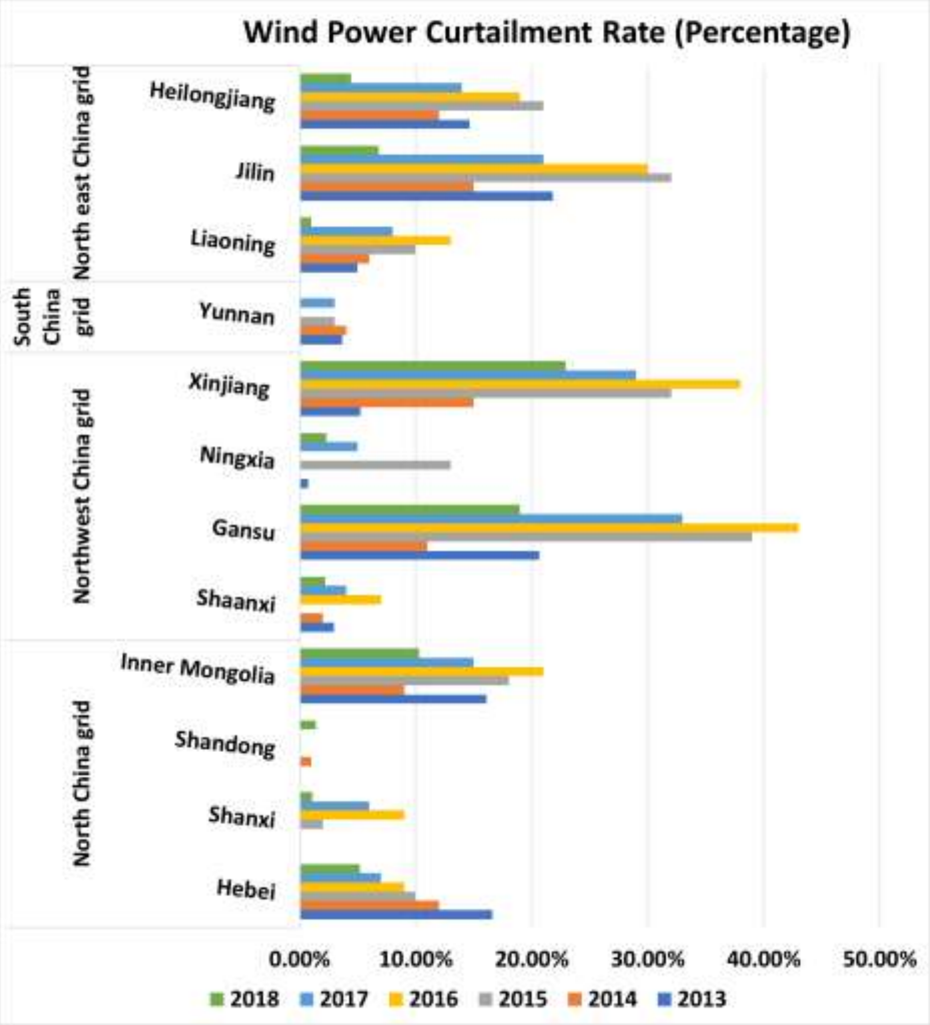
Table.B.1. Basic information of six regional power grids.

	North China Grid	Northeast China Grid	Northwest China Grid	Central China Grid	East China Grid	South China Grid
GDP per capita per year (USD)	10733.40	6914.93	5798.32	6718.55	10743.69	6269.73
Energy consumption per capita per year (kWh)	5441.87	3152.24	6057.88	2621.41	5574.48	3498.72
Population (Thousand people)	273540	109100	104200	381410	260790	250800

Formatted: Font: Not Bold

Appendix C. Supplementary Material for Data Collection

Fig.C.1. Wind power curtailment rate in recorded regions.



Appendix. ~~A~~ D Supplementary Material for Real Option Method

Table. ~~A~~D.1 Code of 10 enterprises

	Full Name	**Code**
Manufacturer	**Xinjiang Goldwind Science & Technology Co., Ltd**	**2208.HK**
	Sinovel Wind Group Co., Ltd.	**601558.SS**
	Dongfang Electric Corporation Limited	**1072.HK**
	Zhuzhou CRRC Times Electric Co., Ltd.	**3898.HK**
	CGN Power Co., Ltd	**1816.HK**
Generator	**Huaneng Power International, Inc.**	**HNP**
	Datang International Power Generation Co., Ltd.	**0991.HK**
	SDIC Power Holdings CO., LTD.	**600886.SS**
	Huadian Power International Corporation Limited	**1071.HK**
	China Resources Power Holdings Company Limited	**0836.HK**

Table. ~~A~~D.2 Descriptive statistics of stock daily return in 10 firms

Code	**HNP**	**0991.HK**	**600886.SS**	**1071.HK**	**0836.HK**
Mean	-7.06E-05	-0.00138	0.000862	0.001818	0.00099
Median	-0.001201	-0.005038	-0.001301	0.00342	-0.000649
Maximum	0.048341	0.043478	0.038136	0.076087	0.056277
Minimum	-0.064502	-0.040404	-0.036458	-0.061856	-0.030211
Std. Dev.	0.019297	0.016383	0.014556	0.027393	0.01692
Skewness	-0.229209	0.256181	-0.038769	0.144004	0.488794
Kurtosis	3.873951	2.995711	3.466009	2.951574	3.328049
Jarque-Bera	3.652265	0.984498	0.836911	0.319853	3.987357
Probability	0.161035	0.61125	0.658062	0.852206	0.136194

Sum	-0.006356	-0.124196	0.077541	0.163657	0.089088
Sum Sq. Dev.	0.033141	0.023888	0.018856	0.066782	0.02548
Observations	90	90	90	90	90

Code	**2208.HK**	**601558.SS**	**1072.HK**	**3898.HK**	**1816.HK**
Mean	-0.002845	0.000705	0.001337	0.000687	-0.000869
Median	-0.006351	0.008403	-0.002232	-0.003561	-0.004914
Maximum	0.119829	0.066038	0.049875	0.051059	0.032967
Minimum	-0.105951	-0.054054	-0.062069	-0.042506	-0.045
Std. Dev.	0.035458	0.020693	0.022094	0.018676	0.013989
Skewness	0.375927	0.305314	0.002183	0.362375	-0.238175
Kurtosis	4.19873	3.745883	3.02367	2.77562	3.519309
Jarque-Bera	7.508392	3.484535	0.002172	2.158536	1.862216
Probability	0.023419	0.175123	0.998914	0.339844	0.394117
Sum	-0.25602	0.063438	0.12034	0.061818	-0.078231
Sum Sq. Dev.	0.1119	0.038111	0.043443	0.031044	0.017418
Observations	90	90	90	90	90

~~Appendix. B Classification of the Current Wind Power FIT Subsidy Categories.~~

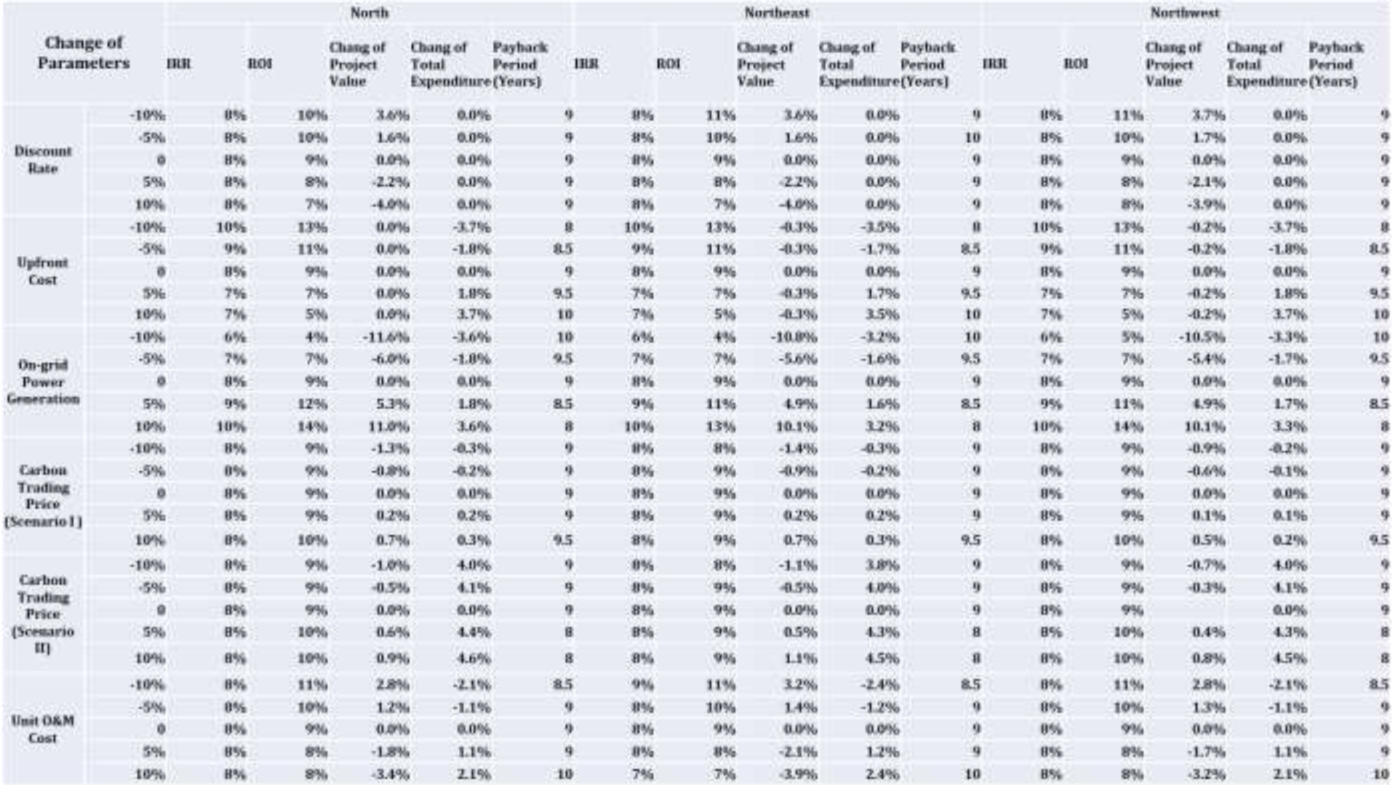
~~Table.B.1 Provinces/ Autonomous regions/ Municipalities included in four categories of wind resources (NDRC).~~

~~**Administrative areas included** (Hu et al., 2013)~~
~~**Category I: Inner Mongolia autonomous region except**: Chifeng, Tongliao, Xing'anmeng, Hulunbeier; **Xinjiang uygur autonomous region**: Urumqi, Yili, Karamay, Shihezi~~
~~**Category II: Hebei province**: Zhangjiakou, Chengde; **Inner Mongolia autonomous region:** Chifeng, Tongliao, Xing'anmeng, Hulunbeier; **Gansu province**: Zhangye, Jiayuguan, Jiuquan~~
~~**Category III: Jilin province**: Baicheng, Songyuan; **Heilongjiang province**: Jixi, Shuangyashan, Qitaihe, Suihua, Yichun, Daxinganling region, **Gansu province except:** Zhangye, Jiayuguan, Jiuquan, **Xinjiang autonomous region except**: Urumqi, Yili, Changji, Karamay, Shihezi, **Ningxia Hui autonomous region**~~
~~**Category IV**: Other parts of China not mentioned above~~

~~Table.B.2 Classification of four wind resource areas~~

~~Category~~	~~Annual average effective wind energy density (D, W/m^2)~~	~~annual cumulative hours (H) of wind speed of 3-20 m/s~~	~~Current government setting wind power FIT price (CNY/kWh)~~
~~I – Rich wind resource areas~~	~~D > 200~~	~~H > 5000~~	~~0.29~~
~~II – Relatively rich wind resource areas~~	~~150 < D < 200~~	~~3000 < H < 5000~~	~~0.34~~
~~III – Available wind resource areas~~	~~50 < D < 150~~	~~2000 < H 3000~~	~~0.38~~
~~IV – Poor wind resource areas~~	~~D < 50~~	~~H < 2000~~	~~0.47~~

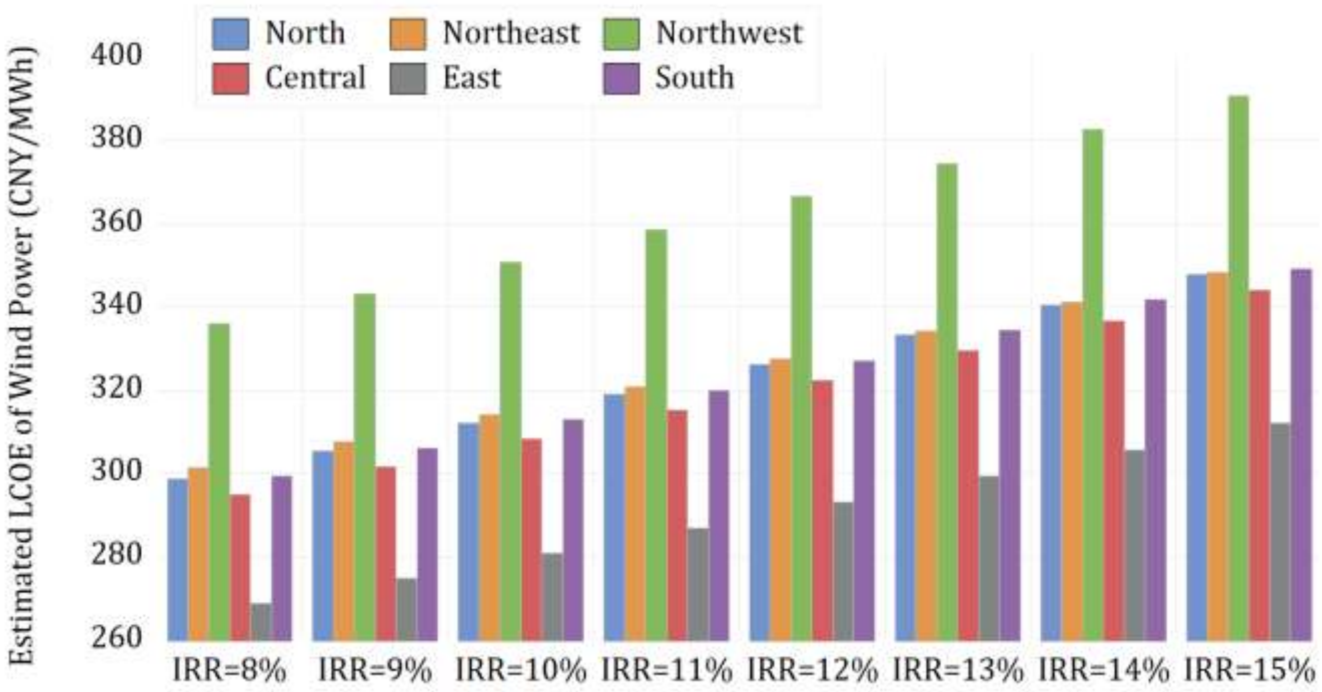
Appendix. ~~C~~E. Sensitivity Analysis (Under the circumstance of IRR=8%)



Change of Parameters		North					Northeast					Northwest				
		IRR	ROI	Chang of Project Value	Chang of Total Expenditure	Payback Period (Years)	IRR	ROI	Chang of Project Value	Chang of Total Expenditure	Payback Period (Years)	IRR	ROI	Chang of Project Value	Chang of Total Expenditure	Payback Period (Years)
Discount Rate	-10%	8%	10%	3.6%	0.0%	9	8%	11%	3.6%	0.0%	9	8%	11%	3.7%	0.0%	9
	-5%	8%	10%	1.6%	0.0%	9	8%	10%	1.6%	0.0%	10	8%	10%	1.7%	0.0%	9
	0	8%	9%	0.0%	0.0%	9	8%	9%	0.0%	0.0%	9	8%	9%	0.0%	0.0%	9
	5%	8%	8%	-2.2%	0.0%	9	8%	8%	-2.2%	0.0%	9	8%	8%	-2.1%	0.0%	9
	10%	8%	7%	-4.0%	0.0%	9	8%	7%	-4.0%	0.0%	9	8%	8%	-3.9%	0.0%	9
Upfront Cost	-10%	10%	13%	0.0%	-3.7%	8	10%	13%	-0.3%	-3.5%	8	10%	13%	-0.2%	-3.7%	8
	-5%	9%	11%	0.0%	-1.8%	8.5	9%	11%	-0.3%	-1.7%	8.5	9%	11%	-0.2%	-1.8%	8.5
	0	8%	9%	0.0%	0.0%	9	8%	9%	0.0%	0.0%	9	8%	9%	0.0%	0.0%	9
	5%	7%	7%	0.0%	1.8%	9.5	7%	7%	-0.3%	1.7%	9.5	7%	7%	-0.2%	1.8%	9.5
	10%	7%	5%	0.0%	3.7%	10	7%	5%	-0.3%	3.5%	10	7%	5%	-0.2%	3.7%	10
On-grid Power Generation	-10%	6%	4%	-11.6%	-3.6%	10	6%	4%	-10.8%	-3.2%	10	6%	5%	-10.5%	-3.3%	10
	-5%	7%	7%	-6.0%	-1.8%	9.5	7%	7%	-5.6%	-1.6%	9.5	7%	7%	-5.4%	-1.7%	9.5
	0	8%	9%	0.0%	0.0%	9	8%	9%	0.0%	0.0%	9	8%	9%	0.0%	0.0%	9
	5%	9%	12%	5.3%	1.8%	8.5	9%	11%	4.9%	1.6%	8.5	9%	11%	4.9%	1.7%	8.5
	10%	10%	14%	11.0%	3.6%	8	10%	13%	10.1%	3.2%	8	10%	14%	10.1%	3.3%	8
Carbon Trading Price (Scenario I)	-10%	8%	9%	-1.3%	-0.3%	9	8%	8%	-1.4%	-0.3%	9	8%	9%	-0.9%	-0.2%	9
	-5%	8%	9%	-0.8%	-0.2%	9	8%	9%	-0.9%	-0.2%	9	8%	9%	-0.6%	-0.1%	9
	0	8%	9%	0.0%	0.0%	9	8%	9%	0.0%	0.0%	9	8%	9%	0.0%	0.0%	9
	5%	8%	9%	0.2%	0.2%	9	8%	9%	0.2%	0.2%	9	8%	9%	0.1%	0.1%	9
	10%	8%	10%	0.7%	0.3%	9.5	8%	9%	0.7%	0.3%	9.5	8%	10%	0.5%	0.2%	9.5
Carbon Trading Price (Scenario II)	-10%	8%	9%	-1.0%	4.0%	9	8%	8%	-1.1%	3.8%	9	8%	9%	-0.7%	4.0%	9
	-5%	8%	9%	-0.5%	4.1%	9	8%	9%	-0.5%	4.0%	9	8%	9%	-0.3%	4.1%	9
	0	8%	9%	0.0%	0.0%	9	8%	9%	0.0%	0.0%	9	8%	9%		0.0%	9
	5%	8%	10%	0.6%	4.4%	8	8%	9%	0.5%	4.3%	8	8%	10%	0.4%	4.3%	8
	10%	8%	10%	0.9%	4.6%	8	8%	9%	1.1%	4.5%	8	8%	10%	0.8%	4.5%	8
Unit O&M Cost	-10%	8%	11%	2.8%	-2.1%	8.5	9%	11%	3.2%	-2.4%	8.5	8%	11%	2.8%	-2.1%	8.5
	-5%	8%	10%	1.2%	-1.1%	9	8%	10%	1.4%	-1.2%	9	8%	10%	1.3%	-1.1%	9
	0	8%	9%	0.0%	0.0%	9	8%	9%	0.0%	0.0%	9	8%	9%	0.0%	0.0%	9
	5%	8%	8%	-1.8%	1.1%	9	8%	8%	-2.1%	1.2%	9	8%	8%	-1.7%	1.1%	9
	10%	8%	8%	-3.4%	2.1%	10	7%	7%	-3.9%	2.4%	10	8%	8%	-3.2%	2.1%	10

Change of Parameters		Central					East					South				
		IRR	ROI	Chang of Project Value	Chang of Total Expenditure	Payback Period (Years)	IRR	ROI	Chang of Project Value	Chang of Total Expenditure	Payback Period (Years)	IRR	ROI	Chang of Project Value	Chang of Total Expenditure	Payback Period (Years)
Discount Rate	-10%	8.0%	11.0%	3.8%	0.0%	9	8.0%	11.0%	3.8%	0.0%	9	8.0%	11.0%	3.8%	0.0%	9
	-5%	8.0%	10.0%	1.8%	0.0%	9	8.0%	10.0%	1.8%	0.0%	9	8.0%	10.0%	1.8%	0.0%	9
	0	8.0%	9.0%	0.0%	0.0%	9	8.0%	9.0%	0.0%	0.0%	9	8.0%	9.0%	0.0%	0.0%	9
	5%	8.0%	9.0%	-2.0%	0.0%	9	8.0%	8.0%	-2.0%	0.0%	9	8.0%	9.0%	-2.0%	0.0%	9
	10%	8.0%	8.0%	-3.8%	0.0%	9	8.0%	7.0%	-3.8%	0.0%	9	8.0%	8.0%	-3.8%	0.0%	9
Upfront Cost	-10%	10.0%	14.0%	-0.2%	-3.7%	8	10.0%	13.0%	-0.1%	-3.6%	8	10.0%	14.0%	-0.1%	-3.7%	8
	-5%	9.0%	12.0%	-0.2%	-1.9%	8.5	9.0%	11.0%	-0.1%	-1.8%	8.5	9.0%	12.0%	-0.1%	-1.9%	8.5
	0	8.0%	9.0%	0.0%	0.0%	9	8.0%	9.0%	0.0%	0.0%	9	8.0%	9.0%	0.0%	0.0%	9
	5%	7.0%	7.0%	-0.2%	1.9%	9.5	7.0%	7.0%	-0.1%	1.8%	9.5	7.0%	7.0%	-0.1%	1.9%	9.5
	10%	7.0%	5.0%	-0.2%	3.7%	10	7.0%	5.0%	-0.1%	3.6%	10	7.0%	5.0%	-0.1%	3.7%	10
On-grid Power Generation	-10%	6.0%	4.0%	-12.5%	-4.1%	10	6.0%	4.0%	-12.7%	-4.0%	10	6.0%	4.0%	-12.2%	-4.0%	10
	-5%	7.0%	7.0%	-6.3%	-2.0%	9.5	7.0%	6.0%	-6.4%	-2.0%	9.5	7.0%	7.0%	-6.2%	-2.0%	9.5
	0	8.0%	9.0%	0.0%	0.0%	9	8.0%	9.0%	0.0%	0.0%	9	8.0%	9.0%	0.0%	0.0%	9
	5%	9.0%	12.0%	6.0%	2.0%	8.5	9.0%	12.0%	6.1%	2.0%	8.5	9.0%	12.0%	5.9%	2.0%	8.5
	10%	10.0%	15.0%	12.2%	4.1%	8	10.0%	14.0%	12.4%	4.0%	8	10.0%	15.0%	12.0%	4.0%	8
Carbon Trading Price (Scenario1)	-10%	8.0%	9.0%	-0.6%	-0.1%	9	8.0%	9.0%	-0.8%	-0.2%	9	8.0%	9.0%	-0.6%	-0.1%	9
	-5%	8.0%	9.0%	-0.4%	-0.1%	9	8.0%	9.0%	-0.5%	-0.1%	9	8.0%	9.0%	-0.4%	-0.1%	9
	0	8.0%	9.0%	0.0%	0.0%	9	8.0%	9.0%	0.0%	0.0%	9	8.0%	9.0%	0.0%	0.0%	9
	5%	8.0%	10.0%	0.1%	0.1%	9	8.0%	9.0%	0.2%	0.1%	9	8.0%	10.0%	0.1%	0.1%	9
	10%	8.0%	10.0%	0.3%	0.1%	9.5	8.0%	9.0%	-0.7%	0.2%	9.5	8.0%	10.0%	0.3%	0.1%	9.5
Carbon Trading Price (Scenario II)	-10%	8.0%	9.0%	-0.5%	4.1%	9	8.0%	9.0%	-0.4%	4.0%	9	8.0%	9.0%	-0.4%	4.1%	9
	-5%	8.0%	9.0%	-0.2%	4.2%	9	8.0%	9.0%	4.7%	4.1%	9	8.0%	9.0%	-0.2%	4.2%	9
	0	8.0%	10.0%	0.0%	0.0%	9	8.0%	9.0%	0.0%	0.0%	9	8.0%	9.0%	0.0%	0.0%	9
	5%	8.0%	10.0%	0.2%	4.3%	8	8.0%	9.0%	0.4%	4.4%	8	8.0%	10.0%	0.2%	4.3%	8
	10%	8.0%	10.0%	0.3%	4.4%	8	8.0%	9.0%	0.7%	4.5%	8	8.0%	10.0%	0.5%	4.4%	8
Unit O&M Cost	-10%	8.0%	11.0%	2.7%	-2.0%	8.5	8.0%	11.0%	3.1%	-2.2%	8.5	8.0%	11.0%	2.7%	-2.1%	8.5
	-5%	8.0%	10.0%	1.3%	-1.0%	9	8.0%	10.0%	1.5%	-1.1%	9	8.0%	10.0%	1.3%	-1.0%	9
	0	8.0%	9.0%	0.0%	0.0%	9	8.0%	9.0%	0.0%	0.0%	9	8.0%	9.0%	0.0%	0.0%	9
	5%	8.0%	9.0%	-1.6%	1.0%	9	8.0%	8.0%	-1.8%	1.1%	9	8.0%	9.0%	-1.6%	1.0%	9
	10%	8.0%	8.0%	-3.0%	2.0%	10	7.0%	7.0%	-3.4%	2.2%	10	8.0%	8.0%	-3.0%	2.1%	10

Appendix. ~~D~~ F Estimated LCOE of Wind Power in Different Regional Power Grids



Reference

21Century Economic Report, 2010. Samples of Wind Farm Revenue: Baseline of IRR=8 [WWW Document]. URL http://business.sohu.com/20100701/n273200787.shtml

Ahmad Dar, A., Anuradha, N., 2018. Comparison: Binomial model and Black Scholes model. Quant. Financ. Econ. 2, 715–730. https://doi.org/10.3934/qfe.2018.1.715

Al–Zhour, Z., Barfeie, M., Soleymani, F., Tohidi, E., 2019. A computational method to price with transaction costs under the nonlinear Black–Scholes model. Chaos, Solitons & Fractals 127, 291–301. https://doi.org/10.1016/J.CHAOS.2019.06.033

Antweiler, W., 2017. A two-part feed-in-tariff for intermittent electricity generation. Energy Econ. 65, 458–470. https://doi.org/10.1016/J.ENECO.2017.05.010

Barbosa, L., Ferrão, P., Rodrigues, A., Sardinha, A., 2018. Feed-in tariffs with minimum price guarantees and regulatory uncertainty. Energy Econ. 72, 517–541. https://doi.org/10.1016/J.ENECO.2018.04.028

Black, F., Scholes, M., 1973. The pricing of options and corporate liabilities. J. Polit. Econ. 81, 637–654.

Black, F., Scholes, M., 1972. American Finance Association The Valuation of Option Contracts and a Test of Market Efficiency. J. Finance 27.

Bøckman, T., Fleten, S.-E., Juliussen, E., Langhammer, H.J., Revdal, I., 2008. Investment timing and optimal capacity choice for small hydropower projects. Eur. J. Oper. Res. 190, 255–267. https://doi.org/10.1016/J.EJOR.2007.05.044

Boer de, D., Renato, R., Huw, S., Qian, G., 2017. The 2017 China Carbon Pricing Survey. https://doi.org/10.1055/s-0032-1315172

Brauneis, A., Mestel, R., Palan, S., 2013. Inducing low-carbon investment in the electric power industry through a price floor for emissions trading. Energy Policy 53, 190–204. https://doi.org/10.1016/J.ENPOL.2012.10.048

Cheng, H.-P., Yu, M.-T., 2013. Effect of the transmission configuration of wind farms on their capacity factors. Energy Convers. Manag. 66, 326–335. https://doi.org/10.1016/J.ENCONMAN.2012.12.011

China Environmental United Certification Center (CEC), 2016. 150MW wind farm project in Pinglu District, Shuozhou City.

Chowdhury, R., Mahdy, M.R.C., Alam, T.N., Al Quaderi, G.D., Arifur Rahman, M., 2020. Predicting the stock price of frontier markets using modified Black–Scholes Option pricing model and machine learning. Phys. A Stat. Mech. its Appl. 124444. https://doi.org/10.1016/J.PHYSA.2020.124444

Davis, G.A., Owens, B., 2003. Optimizing the level of renewable electric R&D expenditures using real options analysis. Energy Policy 31, 1589–1608. https://doi.org/10.1016/S0301-4215(02)00225-2

Devine, M.T., Farrell, N., Lee, W.T., 2017. Optimising feed-in tariff design through efficient risk allocation. Sustain. Energy, Grids Networks 9, 59–74. https://doi.org/10.1016/J.SEGAN.2016.12.003

Dudley, B., 2017. BP Statistical Review of World Energy.

Esmaieli, M., Ahmadian, M., 2018. The effect of research and development incentive on wind power investment, a system dynamics approach. Renew. Energy 126, 765–773. https://doi.org/10.1016/J.RENENE.2018.04.009

Fagiani, R., Barquín, J., Hakvoort, R., 2013. Risk-based assessment of the cost-efficiency and the effectivity of renewable energy support schemes: Certificate markets versus feed-in tariffs. Energy Policy 55, 648–661. https://doi.org/10.1016/J.ENPOL.2012.12.066

Fleten, S.-E., Maribu, K.M., Wangensteen, I., 2007. Optimal investment strategies in decentralized renewable power generation under uncertainty. Energy 32, 803–815. https://doi.org/10.1016/J.ENERGY.2006.04.015

Fuss, S., Johansson, D.J.A., Szolgayova, J., Obersteiner, M., 2009. Impact of climate policy uncertainty on the adoption of electricity generating technologies. Energy Policy 37, 733–743. https://doi.org/10.1016/J.ENPOL.2008.10.022

Gollier, C., Proult, D., Thais, F., Walgenwitz, G., 2005. Choice of nuclear power investments under price uncertainty: Valuing modularity. Energy Econ. 27, 667–685. https://doi.org/10.1016/J.ENECO.2005.04.003

Gu, Y., Xie, L., 2014. Fast sensitivity analysis approach to assessing congestion induced wind curtailment. IEEE Trans Power Syst 29, 101–110.

Hoadley, P., 2020. Option Pricing Models and the "Greeks" [WWW Document]. URL https://www.hoadley.net/options/bs.htm

Hsu, Y.-S., Wu, C.-H., 2020. Extended Black and Scholes model under bankruptcy risk. J. Math. Anal. Appl. 482, 123564. https://doi.org/10.1016/J.JMAA.2019.123564

Hu, Z., Wang, J., Byrne, J., Kurdgelashvili, L., 2013. Review of wind power tariff policies in China. Energy Policy 53, 41–50. https://doi.org/10.1016/J.ENPOL.2012.09.057

Kim, K.-K., Lee, C.-G., 2012. Evaluation and optimization of feed-in tariffs. Energy Policy 49, 192–203. https://doi.org/10.1016/J.ENPOL.2012.05.070

Kim, K.-T., Lee, D.-J., Park, S.-J., 2014. Evaluation of R&D investments in wind power in Korea using real option. Renew. Sustain. Energy Rev. 40, 335–347. https://doi.org/10.1016/J.RSER.2014.07.165

Li, C. bin, Lu, G. shu, Wu, S., 2013. The investment risk analysis of wind power project in China. Renew. Energy 50, 481–487. https://doi.org/10.1016/j.renene.2012.07.007

Lin, B., Wesseh, P.K., 2013. Valuing Chinese feed-in tariffs program for solar power generation: A real options analysis. Renew. Sustain. Energy Rev. 28, 474–482. https://doi.org/10.1016/j.rser.2013.08.043

Liu, D., 2012. Authorized renewable energy power generation connected to grid and it's combined margin methodology [WWW Document]. Glob. Clim. Chang. Res. Inst.

Liu, X., Ronn, E.I., 2020. Using the binomial model for the valuation of real options in computing optimal subsidies for Chinese renewable energy investments. Energy Econ. 87, 104692. https://doi.org/10.1016/J.ENECO.2020.104692

Liu, Y., Zhang, J., 2018. Research on the effects of wind power grid to the distribution network of Henan province. AIP Conf. Proc. 1955. https://doi.org/10.1063/1.5033604

Luo, G., Li, Y., Tang, W., Wei, X., 2016. Wind curtailment of China׳s wind power operation: Evolution, causes and solutions. Renew. Sustain. Energy Rev. 53, 1190–1201. https://doi.org/10.1016/J.RSER.2015.09.075

MF, 2015. the Notice on Value-added Tax Policy of Wind Power Generatio.

Ministry of Industry and Information Technology, 2019. The carbon trading price trend in China [WWW Document]. URL http://www.tanpaifang.com/tanhangqing/

Ministry of Industry and Information Technology, 2018. The operating hours of wind farms in China [WWW Document]. URL http://www.cec.org.cn/yaowenkuaidi/2019-01-29/188549.html

National Bureau of Statistics, 2019. China Statistical Yearbook 2018.

NDRC, 2019a. Notice on work related to wind power and photovoltaic power generation connected to grid without subsidy [WWW Document]. URL http://bgt.ndrc.gov.cn/zcfb/201901/t20190109_925402.html

NDRC, 2019b. the Notice on Improving Wind Energy Generated Electricity On-grid Power Tariff Policy [WWW Document]. 2019. URL http://www.ndrc.gov.cn/zwfwzx/zfdj/jggg/201905/t20190524_936696.html

NDRC, 2019c. the Sheet of National Onshore Wind Power Feed-in-tariff Price 2019 [WWW Document]. URL http://www.gov.cn/xinwen/2019-05/25/content_5394615.htm

NDRC, 2017a. the Sheet of National Onshore Wind Power Feed-in-tariff Price [WWW Document]. URL http://www.ndrc.gov.cn/zwfwzx/zfdj/jggg/201612/W020161228343602191833.pdf

NDRC, 2017b. National carbon emissions trading market development plan （Power Generation Industry) 1–7.

NDRC, 2016a. Notice on Improving Wind Energy Generated Electricity On-grid Power Tariff Policy [WWW Document]. URL http://news.bjx.com.cn/html/20151215/691707-2.shtml

NDRC, 2016b. China's regional grid combined margin emission factor.

NDRC, 2016c. the Sheet of National Onshore Wind Power Feed-in-tariff Price [WWW Document]. URL http://news.bjx.com.cn/html/20151215/691707-2.shtml

NDRC, 2015a. Notice on Improving Wind Energy Generated Electricity On-grid Power Tariff Policy [WWW Document]. URL http://www.ndrc.gov.cn/fzgggz/jggl/zcfg/201501/t20150109_748460.html

NDRC, 2015b. Notice on guaranteeing the purchasing of electricity generated by using regenerable energy resources in full amount 1–8.

NDRC, 2015c. the Sheet of National Onshore Wind Power Feed-in-tariff Price [WWW Document]. URL http://www.ndrc.gov.cn/fzgggz/jggl/zcfg/201501/t20150109_748460.html

NDRC, 2014. the Notice on Improving Wind Energy Generated Electricity On-grid Power Tariff Policy, NDRC, retrieved from [WWW Document]. URL http://www.ndrc.gov.cn/fzgggz/jggl/zcfg/200907/t20090727_748211.html

NDRC, 2011. Notice on Pilot Work on Carbon Emissions Trading [WWW Document]. URL http://www.ndrc.gov.cn/zcfb/zcfbtz/201201/t20120113_456506.html

NDRC, 2009a. Notice on Improving Wind Energy Generated Electricity On-grid Power Tariff Policy [WWW Document]. URL http://www.ndrc.gov.cn/zcfb/zcfbtz/200907/W020090727530432780298.pdf

NDRC, 2009b. National Development and Reform Commission [WWW Document]. URL http://jgs.ndrc.gov.cn/zttp/zyhjjg/200705/t20070508_133828.html

NEA, 2013. the Notice of the National Energy Administration Concerning Issuing the Guiding Opinions on Energy-related Work [WWW Document]. URL http://www.cec.org.cn/yaowenkuaidi/2013-01-18/96345.html

Penizzotto, F., Pringles, R., Olsina, F., 2019. Real options valuation of photovoltaic power investments in existing buildings. Renew. Sustain. Energy Rev. 114, 109308. https://doi.org/10.1016/j.rser.2019.109308

Pringles, R., Olsina, F., Garcés, F., 2015. Real option valuation of power transmission investments by stochastic simulation. Energy Econ. 47, 215–226. https://doi.org/10.1016/J.ENECO.2014.11.011

Ragheb, M., 2017. Economics of wind energy. Mod. Energy Rev. 209–236. https://doi.org/10.1049/et:20081522

REUTERS, 2017. China banks start to lower discounts on mortgage rates: paper [WWW Document]. 2017.

URL https://www.reuters.com/article/us-china-economy-mortgages/china-banks-start-to-lower-discounts-on-mortgage-rates-paper-idUSKBN15O0AA

Rigter, J., Vidican, G., 2010. Cost and optimal feed-in tariff for small scale photovoltaic systems in China. Energy Policy 38, 6989–7000. https://doi.org/10.1016/J.ENPOL.2010.07.014

Ritzenhofen, I., Spinler, S., 2016. Optimal design of feed-in-tariffs to stimulate renewable energy investments under regulatory uncertainty — A real options analysis. Energy Econ. 53, 76–89. https://doi.org/10.1016/J.ENECO.2014.12.008

Schmidt, J., Lehecka, G., Gass, V., Schmid, E., 2013. Where the wind blows: Assessing the effect of fixed and premium based feed-in tariffs on the spatial diversification of wind turbines. Energy Econ. 40, 269–276. https://doi.org/10.1016/J.ENECO.2013.07.004

SecuritiesIndustrial, 2013. The profit calculation from renewable energy.

Shen, J., Luo, C., 2015. Overall review of renewable energy subsidy policies in China – Contradictions of intentions and effects. Renew. Sustain. Energy Rev. 41, 1478–1488. https://doi.org/10.1016/J.RSER.2014.09.007

Si, L.B., Meng, W.D., Qiao, H.Y., 2011. Gap analysis between the self-innovation ability and market share of the wind-power equipment whole-machine manufacturing enterprises at home and abroad. Ecol Econ 5, 157–159.

Soberón, A., Stute, W., 2017. Assessing skewness, kurtosis and normality in linear mixed models. J. Multivar. Anal. 161, 123–140. https://doi.org/10.1016/J.JMVA.2017.07.010

Wang, Q., 2010. Effective policies for renewable energy—the example of China’s wind power—lessons for China’s photovoltaic power. Renew. Sustain. Energy Rev. 14, 702–712. https://doi.org/10.1016/J.RSER.2009.08.013

Wang, X., Cai, Y., Dai, C., 2014. Evaluating China’s biomass power production investment based on a policy benefit real options model. Energy 73, 751–761. https://doi.org/10.1016/J.ENERGY.2014.06.080

Wei, Y.-M., Chen, H., Chyong, C.K., Kang, J.-N., Liao, H., Tang, B.-J., 2018. Economic dispatch savings in the coal-fired power sector: An empirical study of China. Energy Econ. 74, 330–342. https://doi.org/10.1016/J.ENECO.2018.06.017

Wesseh, P.K., Lin, B., 2016. A real options valuation of Chinese wind energy technologies for power generation: do benefits from the feed-in tariffs outweigh costs? J. Clean. Prod. 112, 1591–1599. https://doi.org/10.1016/J.JCLEPRO.2015.04.083

Yang, C., Ge, Z., 2018. Dynamic feed-in tariff pricing model of distributed photovoltaic generation in China. Energy Procedia 152, 27–32. https://doi.org/10.1016/J.EGYPRO.2018.09.054

Yin, S., Zhang, S., Andrews-Speed, P., Li, W., 2017. Economic and environmental effects of peak regulation using coal-fired power for the priority dispatch of wind power in China. J. Clean. Prod. 162, 361–370. https://doi.org/10.1016/J.JCLEPRO.2017.06.046

Zhang, M.M., Zhou, D.Q., Zhou, P., Liu, G.Q., 2016. Optimal feed-in tariff for solar photovoltaic power generation in China: A real options analysis. Energy Policy 97, 181–192. https://doi.org/10.1016/J.ENPOL.2016.07.028

Zhang, R., Ni, M., Shen, G.Q.P., Wong, J.K.W., 2019a. An analysis on the effectiveness and determinants of the wind power Feed- in-Tariff policy at China ’ s national-level and regional-grid-level An analysis on the effectiveness and determinants of the wind power Feed- in-Tariff policy at China ’ s national. Sustain. Energy Technol. Assessments 34, 87–96. https://doi.org/10.1016/j.seta.2019.04.010

Zhang, R., Shen, G.Q.P., Ni, M., Wong, J.K.W., 2019b. An overview on the status quo of onshore and offshore wind power development and wind power enterprise localization in China. Int. J. Green Energy 16, 1646–1664. https://doi.org/10.1080/15435075.2019.1681429

Zhao, X., Yao, J., Sun, C., Pan, W., 2018. Impacts of carbon tax and tradable permits on wind power investment in China. Renew. Energy. https://doi.org/10.1016/J.RENENE.2018.09.068

Zhao, Z.-Y., Chang, R.-D., Chen, Y.-L., 2016a. What hinder the further development of wind power in China?—A socio-technical barrier study. Energy Policy 88, 465–476. https://doi.org/10.1016/J.ENPOL.2015.11.004

Zhao, Z.-Y., Chen, Y.-L., Chang, R.-D., 2016b. How to stimulate renewable energy power generation effectively? – China's incentive approaches and lessons. Renew. Energy 92, 147–156. https://doi.org/10.1016/J.RENENE.2016.02.001

Zhu, L., Fan, Y., 2011. A real options–based CCS investment evaluation model: Case study of China's power generation sector. Appl. Energy 88, 4320–4333. https://doi.org/10.1016/J.APENERGY.2011.04.005