NORTH CHINA ELECTRIC POWER UNIVERSITY

Stranded Coal Power in Jilin:
Risks and Policy Implications

Policy Report

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Disclaimer

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Table of Contents

Key Finding

- The future for Jilin's coal power is highly uncertain, with many risk factors. Flat demand growth and oversupply has seriously reduced the economic return of coal power in this province. Meanwhile, the environmental pollutant and abatement requirement, the upcoming national carbon market, and the vast potential of renewable deployment have all added to the uncertainty of coal power in this province.
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- According to the coal power pre-warning information issued by the National Energy Administration (NEA) in April 2016, Jilin has double alerts in coal power planning and construction risk indicator and resource adequacy indicator. Since 2014, Jilin has closed 1700 MW ageing or heavily polluted coal units. In September 2016, NEA also required cancellation of three coal projects located in Jilin. However, the total capacity of the coal power projects under construction and planning in Jilin is as high as 7070 MW. In addition, the high share of combined heat and power (CHP) units in the entire coal fleet represents a huge challenge in Jilin.
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- With a power capacity expansion model, this report first quantifies the rational coal power capacity, prioritising renewable energy development based upon electricity demand growth scenarios in Jilin during the 13th FYP (five-year plan) period. The estimated scale of excess coal power capacity ranges between 8190 MW and 18,480 MW by 2020, depending on different combinations of assumptions in demand growth, wind power capacity growth, and coal power capacity installation. With a recommended scenario of medium demand growth and low wind capacity growth, the scale of excess coal capacity will range between 9000 MW and 16070 MW, assuming that all the new projects will be commissioned for the upper bound.
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- This report employs a project evaluation model to assess the stranded assets value according to the number of years of the coal power plant being stranded. In our study, the stranded assets value consists of the uncovered initial investment, the unpaid investment return requirement, and the unpaid tax due to stranding. To model the uncertainty of stranding time and its impact, three time windows, 2020, 2025, and 2030, are selected for valuation analysis. Under the most ideal scenario, in which all the new coal projects will be cancelled, the total value of stranded assets will be RMB 46.2, 29.1, and 14.9 billion by 2020, 2025, and 2030, respectively. Under the worst scenario, in which all the new coal projects will be commissioned, the total value of stranded assets will reach RMB 99.2, 66.1, and 37.5 billion by 2020, 2025, and 2030, respectively, more than the double the ideal scenario. Even under the medium scenario, in which only half of the new projects will be commissioned, the total value of stranded assets will reach RMB 78.1, 51.6, and 28.6 billion by 2020, 2025, and 2030, respectively.

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- On the company level, the top four generation utilities, namely Guodian, China Power Investment, Huaneng, and Datang, are confronted with a big stranded assets risk. The Guodian Group will have the most stranded capacity, due to the ageing and inefficient fleet. However, as the China Power Investment Group has the most new projects under construction, it will experience higher loss of stranded assets if these projects are normally commissioned. Under the assumption that all new projects are commissioned, Guodian, Huaneng, China Power Investment, and Datang will experience stranded assets valued at RMB 23.09, 20.08, 25.7, and 22.1 billion, respectively.
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- Stranded assets will lead to losses at the levels of company, investor, financial institution, employee, and local government. The strictest regulation policy should be employed to cancel or postpone the commission of new projects. With measures including regular or early retirement, and back pressure CHP retrofitting, the present generation capacity can be effectively curtailed. In addition, flexibility retrofitting can be deployed within existing capacity to facilitate the integration of renewable energy and provide new market opportunity for the stranded capacity in the power market environment.
- This report suggests several measures: establishing a special fund for structure adjustment to support closing ageing units, CHP, or flexibility retrofitting; taking advantage of the pilot reform of ancillary service market to accelerate power market reform and explore a new business model for coal power transiting from serving base load to serving ancillary service, and promoting green financing to facilitate the investment the transition from coal power to renewable and clean energy.

Executive Summary

To the best of our knowledge, this is the first provincial case study on the exposure of coal-fired power plants in China to environment-related risks that can create ‘stranded assets’. Stranded assets are assets that have suffered from unanticipated or premature write-downs, devaluations, or conversion to liabilities.[1] The environment-related risks facing coal-fired power stations are substantial and could be significant drivers of asset stranding.

By the end of 2015, the total generation capacity installed in Jilin reached 27,185 MW, of which 17,830 MW was thermal power (65.5%)[2], 3790 MW was hydropower (13.9%), 4920 MW was wind power (18.1%), and 645 MW was solar (0.3%) and others (2.1%).[3] Status analysis identifies weak electricity demand growth in Jilin due to economic restructuring and de-capacity in energy-intensive industry and much slower demand growth compared with the national average. In 2015, the electricity consumption growth rate was negative, and serious oversupply appeared in this province. Since 2014, Jilin has closed 1700 MW ageing or heavily polluted coal units.[4,5] In September 2016, NEA also required cancellation of three coal projects located in Jilin.[6] However, the total capacity of coal power projects under construction in Jilin is as high as 7070 MW.[7]

Jilin is the old industrial base in China and has made a great contribution to the industrialisation of this country. However, in recent years, the side effects of extensive growth mode, in particular resource shortage, environmental deterioration, and persistent and severe haze have interfered with the social and economic development in this province.

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[1] Ben Caldecott, Nicholas Howarth, Patrick McSharry, “ Stranded Assets in Agriculture: Protecting Value from Environment-related Risks”, Stranded Assets Programme, SSEE, University of Oxford, August 2013.

[2] Energy Bureau of Jilin Province, "The local absorption pilot program of renewable energy resources in Jilin Province”, <吉林省可再生能源就近消纳试点方案>, 2016.

[3] State Grid Jilin Province Electric Power Supply Company, “Operation mode of Jilin power grid in 2016”, <2016 年吉林电网运行方式>, 2016.

[4] Economic and Technical Research Institute of State Grid Jilin Province Electric Power Supply Company, “Report on the development planning of Jilin power grid in 13th FYP period",<吉林电网“十三五”发展规划总报告>, 2014.

[5] Energy Bureau of Jilin Province, “Power generation expected control objectives of Jilin Province in 2016”, <吉林省2016 年发电预期调控目标>, 2016.

[6] National Energy Administration, “Notice on the abolition of a number of coal projects without approval of the construction conditions”, <关于取消一批不具备核准建设条件煤电项目的通知>, 2016.

[7] Greenpeace, “New coal project database in China during 2012 to June 2016”, 2016 (Note: part of the data were processed by the University of Oxford).

In response, Jilin's provincial government has accelerated efforts to curb pollution issues. A clean air action plan (2016–2020) issued by Jilin's provincial government[8] in June 2016 made a firm commitment to capping coal consumption and accelerating energy mix adjustment while defining the main objectives and the timetable of atmospheric pollution prevention and control. In a policy document on the Coordinated Development of Power Sector in Northeast China,[9] NEA also requires completion of ultra-low emission retrofitting of coal power plants sized at 300 MW and above in Northeast regions by 2018. In Jilin, 12,000 MW of coal capacity is sized at 300 MW and above. As the actual emission performance of these plants is generally much higher than the national average, they will incur expensive retrofitting expenditure when complying with this strict emission standard.

Furthermore, China has made a commitment to renewable energy transition, and the target for 2020 is 15% non-fossil energy supply.[10] At the national level, a Chinese renewable portfolio standard (RPS) has been proposed by the NEA, and it requires that non-hydropower renewable generation in all generation companies (with the exemption of specialised non-fossil energy companies) should reach 9% of their total power generation by 2020.[11] As one of the leading renewable energy provinces, Jilin is required to generate more than 13% renewable energy in its overall generation. The information is very clear here: In this province, the market space for coal power will be largely squeezed in the future.

Even since 2014, with the increasing economic downturn pressure, severe oversupply of electric power has emerged in the Northeast region. In particular, the annual utilisation rate of generation units in the Northeast region has continually ranked last in China. Data from the Jilin Energy Bureau can partly reveal the main problems. Firstly, there is serious oversupply, with more than 40 TWh excess generation capacity. Secondly, the generation capacity of CHP units reaches 13,148.4 MW, accounting for 74% of coal fleet and being 8000 MW larger than the minimum system load and 4000 MW larger than the maximum system load.[12] Lastly, by the end of 2015, the total coal power capacity in Jilin was 18,000 MW, while

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[8] Jilin provincial government, "Jilin's clean air action plan (2016–2020)", <吉林省空气清洁行动计划（2016–2020 年）>, 2016.

[9] National Energy Administration, "Coordinated Development of Power Sector in Northeast China", <关于推动东北地区电力协调发展的实施意见>, 2016.

[10] The State Council, "National Planning for Climate Change (2014–2020)", <国家应对气候变化规划（2014–2020 年）>, 2014.

[11] National Energy Administration, "Guidance on the establishment of target guidance system of renewable energy development and utilization ", <关于建立可再生能源开发利用目标引导制度的指导意见>, 2016.

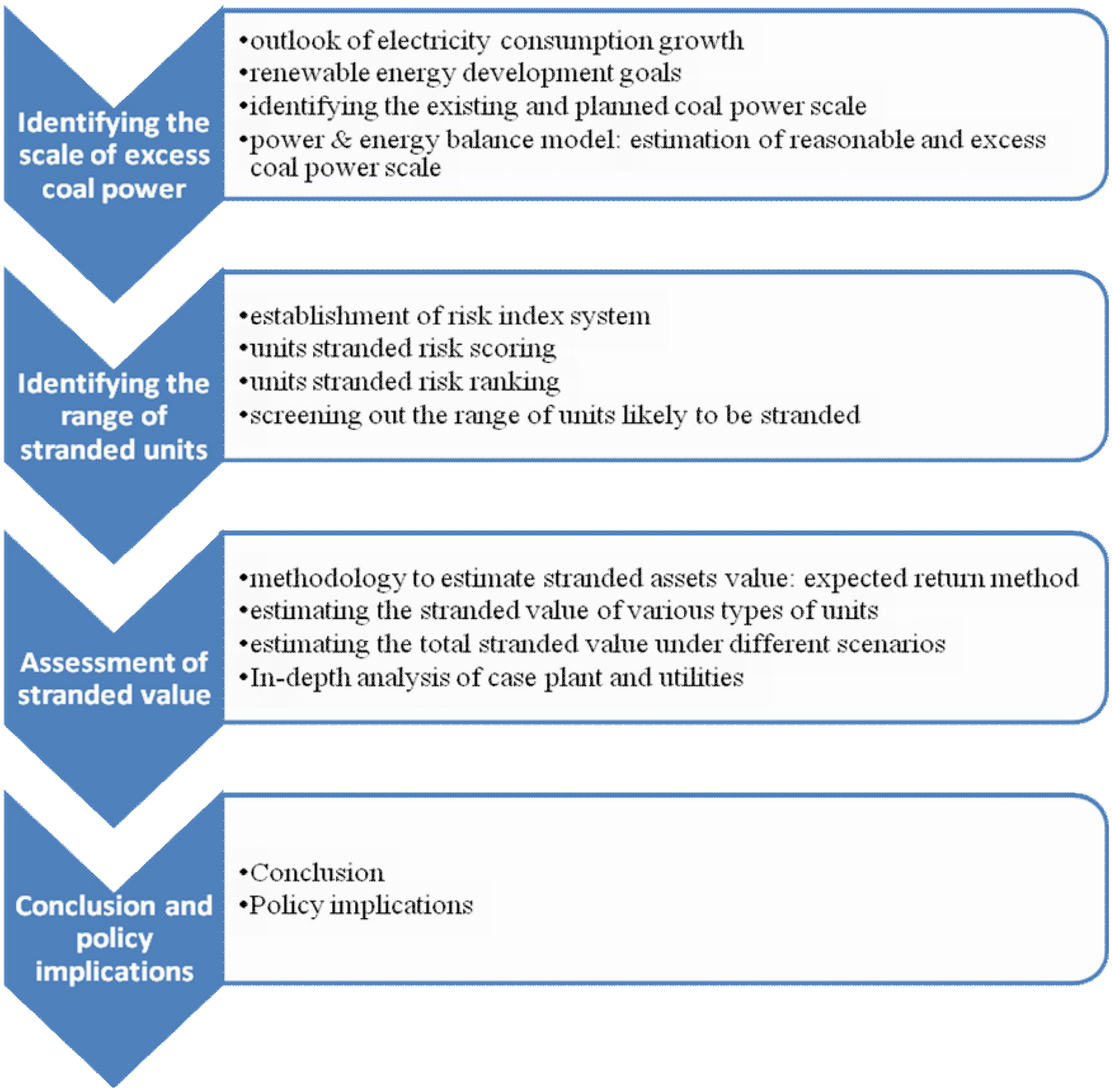
[12] Polaris Wind Power net, "How to solve the power surplus problem in Jilin with high wind curtailment rate?" , 2016, http://news.bjx.com.cn/html/20160711/750042.shtml

the annual utilisation rate was merely 3362 h, much lower than the national average.[13] As a province with red readings in the capacity adequacy indicator and the planning and construction indicator, Jilin's coal power sector will face heavy phase-out pressure.[14]

Methodology

The methodology and the research process are shown in Figure 1.

Figure 1 The methodology and process of the study

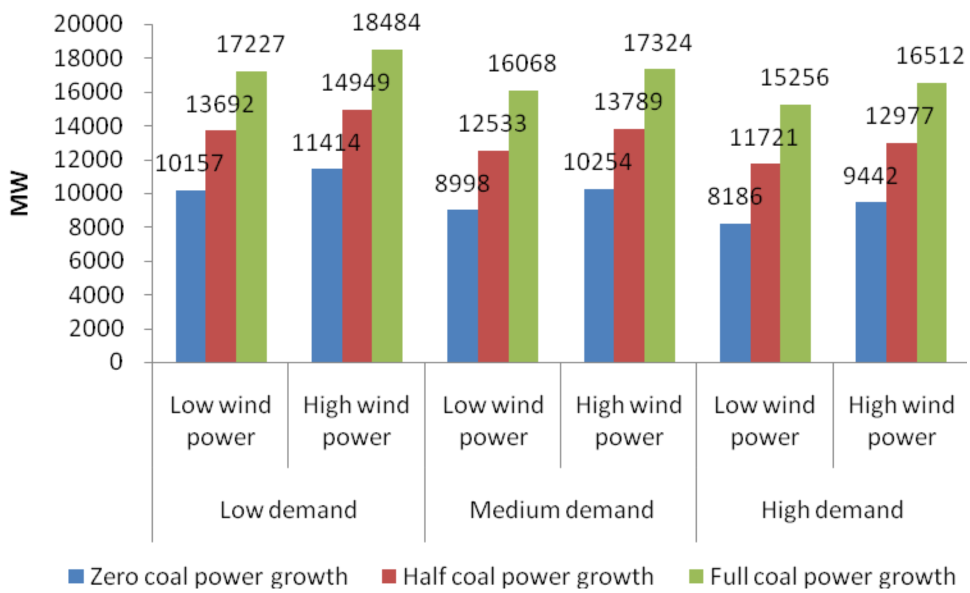


[13]National Energy Administration, "Average Utilization Hours Situation of Power Generation Units of 6,000 kW or More in China in 2015", <2015 年全国 6000 千瓦及以上电厂发电设备平均利用小时情况>, 2016, http://www.nea.gov.cn/2016-01/29/c_135056890.htm

[14]National Energy Administration, "Risk alert mechanism of coal power planning and construction", <煤电规划建设风险预警机制>, 2016.

To identify the potential scale of excess coal power, we conducted a scenario study for electricity demand and then employed a power capacity expansion model to estimate the rational scale of coal capacity (see Appendix Ⅰ). According to the recent trend of electricity consumption growth and the future social and economic development, the range of the scenario of electricity demand growth in Jilin during the 13th FYP period is set as 2%–4.5% annually, with 3.5% as the recommended scenario. Then, prioritising renewable energy development, we use a power generation capacity expansion model to quantify the rational scale of coal power; the estimated excess capacity of coal power by 2020 ranges from 8186 MW to 18,484 MW under different scenario settings. Under the recommended scenario setting of medium electricity demand growth and slow wind capacity growth, we find that the excess coal capacity will be about 9000 MW by 2020 in Jilin.

Figure 2 Estimate of excess coal power capacity under different scenarios by 2020



The approach we have used in this report is based on the methods pioneered in a previous report of the Sustainable Finance Programme of the University of Oxford's Smith School of Enterprise and the Environment from March 2015, entitled Stranded Assets and Subcritical Coal: the risk to companies and investors.[15]This methodology was significantly expanded in a landmark publication,[16]Stranded Assets and Thermal Coal: An analysis of environment-related risks, published by the Oxford Smith School in February 2016. In May 2016, the Oxford Smith School employed the same methodology to publish another comprehensive

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[15]Ben Caldecott, Gerard Dericks and James Mitchell et al., "Stranded Assets and Subcritical Coal: The Risk to Companies and Investors", Stranded Assets Programme, SSEE, University of Oxford, March 2015.

[16]Ben Caldecott, Lucas Kruitwagen, Gerard Dericks et al., "Stranded Assets and Thermal Coal: An analysis of environment-related risks", Stranded Assets Programme, SSEE, University of Oxford, February 2016.

national analysis report,[17]entitled Stranded Assets and Thermal Coal in Japan: An analysis of environment-related risk exposure.

This report uses similar data and methods to provide a high-resolution examination of the environment-related risks facing Jilin's thermal coal assets. Understanding how environment-related factors interact and affect a company requires a detailed examination of the company's specific asset base. For all of Jilin's utilities, we have analysed the attributes of their coal-fired power stations and integrated and cross-referenced this data with indicators of environment-related risk to develop asset-specific analyses of risk exposure. We have then aggregated these analyses to the company level to provide company-wide assessments of environment-related risk exposure.

Table 1 Local and generator risk hypotheses

Utility exposure to LRHs	Name	Source
NO.1	Baseline water stress	WRI's Aqueduct
NO.2	CCS	CARMA/CoalSwarm/WEPP/Geogreen, Global CCS Institute
NO.3	Heat stress	IPCC AR5
NO.4	Pollutant index	Boys et al. (2014)/NASA's SEDAC
Utility exposure to GRHs	**Name**	**Source**
NO.1	Service length	CARMA/CoalSwarm/WEPP/Greenpeace
NO.2	Unit capacity	CARMA/CoalSwarm/WEPP/Greenpeace
NO.3	Heat rate	CARMA/CoalSwarm/WEPP/Greenpeace
NO.4	Pollutant emissions	CARMA/CoalSwarm/WEPP/Greenpeace

Our approach requires us to take a view on what the environment-related risks facing coal-fired power stations could be and how they could affect asset values. In the national report for Japan, Local Risk Hypotheses (LRHs) and National Risk Hypotheses (NRHs) are differentiated, based on whether the risk factor in question affects all assets in a similar way or if risk exposure is specific to the local environment. With consolidation and simplification, we employ Local Risk Hypotheses (LRHs) and Generator Risk Hypotheses (GRHs) in this report. As water stress, for example, varies across the province, it is an LRH, whereas service year and heat rate are GRHs. The list of these LRHs and GRHs can be found below in Table 1 with a brief description.

[17]Ben Caldecott et al.," Stranded Assets and Thermal Coal in Japan: An analysis of environment-related risk exposure," Stranded Assets Programme, SSEE, University of Oxford, May 2016.

The scale of stranded assets

Considering the differences in the performance and return of different size units, we divide coal plants into five categories. In China, we cannot obtain the market value for every power plant because only major generation groups and big independent power producers are publicly listed. In this report, we use the value expectation of a power plant for its entire service life to estimate its stranded value. We define the value of stranded assets as the sum of unrecovered initial investment, unpaid investor's return requirement, and unpaid tax due to stranding（see appendix Ⅱ for the method of calculation. The underlying assumptions are as follows: 30 years as service life, 20 years for deprecation, with straight-line depreciation method, 15 years for loan repayment, 5% of initial investment for the scrap assets' value when decommissioned (see appendixⅢ for parameter setting). In the assessment model, the benchmarking on-grid price for desulphurised and denitrified coal power in Jilin is 0.37 RMB/KWh, and the share of bilateral trading in total generation is set as 10%, with 0.1 RMB/KWh reduction relative to the on-grid price.

Table 2 The composition of coal power units in Jilin

Category				installed	Under construction	Under planning	Total
		sum	unit	86	2	12	100
			MW	18627	700	6370	25697
Among which	**≥1000 MW**	subtotal	unit	0	0	4	4
			MW	0	0	4000	4000
	600 MW–1000 MW	subtotal	unit	6	0	2	8
			MW	3980	0	1320	5300
	300 MW–600 MW	subtotal	unit	25	2	3	30
			MW	8350	700	950	10000
	200 MW–300 MW	subtotal	unit	20	0	0	20
			MW	4020	0	0	4020
	<200 MW	subtotal	unit	35	0	3	38
			MW	2277	0	100	2377

(Data source: University of Oxford, "Information table of coal power units in Jilin.)

In China, 1000 MW USC unit is the most advanced technology. If such a unit were stranded when commissioned, the total value loss for its entire service life would reach as high as 22.46 billion RMB. In Jilin province, four 1000 MW USC units will be commissioned by 2019. If fully stranded, the stranded assets value would be around 90 billion RMB, about 1.5 times the national deficit in renewable energy funds. In Jilin, there are 38 coal units sized below 200

MW with low operational efficiency. Phasing out inefficient coal power will immediately strand these units. The total stranded assets deserve careful attention.

Table 3 Stranded assets estimate for different sized coal units

	Heat rate (Kgce/MWh)	Utilisation (hour)	Build cost (RMB/KW)	Auxiliary rate (%)	Stranded value (100 Million)
≥1000 MW	289	5255	3202	4.28	224.61
600 MW–1000 MW	311	4868	3400	5.34	104.35
300 MW–600 MW	313	4355	4100	5.88	39.67
200 MW–300 MW	331	4157	4300	7.81	19.75
<200 MW	334	4810	4500	8.12	14.82

(Data source: CEC 2014)

A total of 7070 MW new coal capacity is under construction. The actual commissioned capacity can vary subject to the actual implementation of the regulation and control policy by NEA. Thus, we consider three scenarios relating to this critical factor.

Scenario 1 (optimistic and Policy scenario) assumes that all the new coal projects (including both those under construction and in planning) would be suspended. In this scenario, there will be no growth in coal capacity during the 13th FYP period in Jilin. According to the power planning model, we can estimate the excess capacity of coal power for different years: 9186 MW in 2016, 9076 MW in 2017, 9293 MW in 2018, 9360 MW in 2019, and 8998 MW in 2020. We further assume that all the new demand since 2020 can be met with renewable energy and that the excess capacity after 2020 will therefore remain unchanged.

Scenario 2 (practical scenario) assumes that half of the new coal projects would be built by 2019 but that there would be no new installations after 2020. According to the power planning model, we can estimate the excess capacity of coal power for different years: 9186 MW in 2016, 9076 MW in 2017, 9643 MW in 2018, 12,895 MW in 2019, and 12,533 MW in 2020.

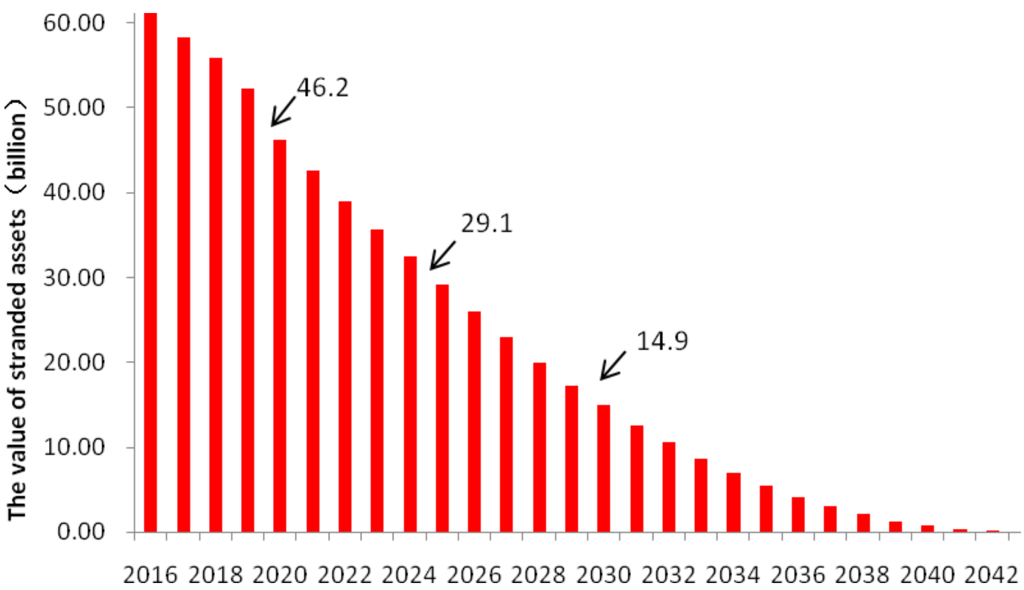
Scenario 3 (pessimistic and Reference scenario) assumes that all the new coal projects would be built by 2019 but that there would be no new installations after 2020. According to the power planning model, we can estimate the excess capacity of coal power in different years: 9186 MW in 2016, 9076 MW in 2017, 9993 MW in 2018, 16,430 MW in 2019, and 16,068 MW in 2020.

According to the estimate of excess capacity and the scoring of stranded risks, we screen out a long list of most likely stranded units in Jilin. Then we can estimate the total stranded assets' value according to their sizes and stranded service years.

In addition to the estimated asset stranding charges, we overlay three different year windows to remove coal-fired generation from the energy system: 5 years, 10 years, and 15 years. We select these three windows as they are compatible with the impact of risk factors chosen previously, such as regional risk factors, including atmospheric pollution, carbon capture and storage (CCS) and baseline water stress (BWS), and generator risk factors, including operation year, heat rate, and pollutant emissions performance.

In Scenario 1 and its baseline situation—the most extreme case, where coal power is decommissioned now—the total impairment charges would be RMB63.3 billion in 2016. In the 5-year window (2020), total asset stranding charges are RMB46.2 billion. The standing charges in the 10-year window (2025) are RMB29.1 billion. Finally, the 15-year scenario estimates total asset stranding charges to be RMB 14.9 billion. The linear decrease in stranded charges of existing capacity along the time horizon is due to the partial recovery of stranded assets through operation and depreciation.

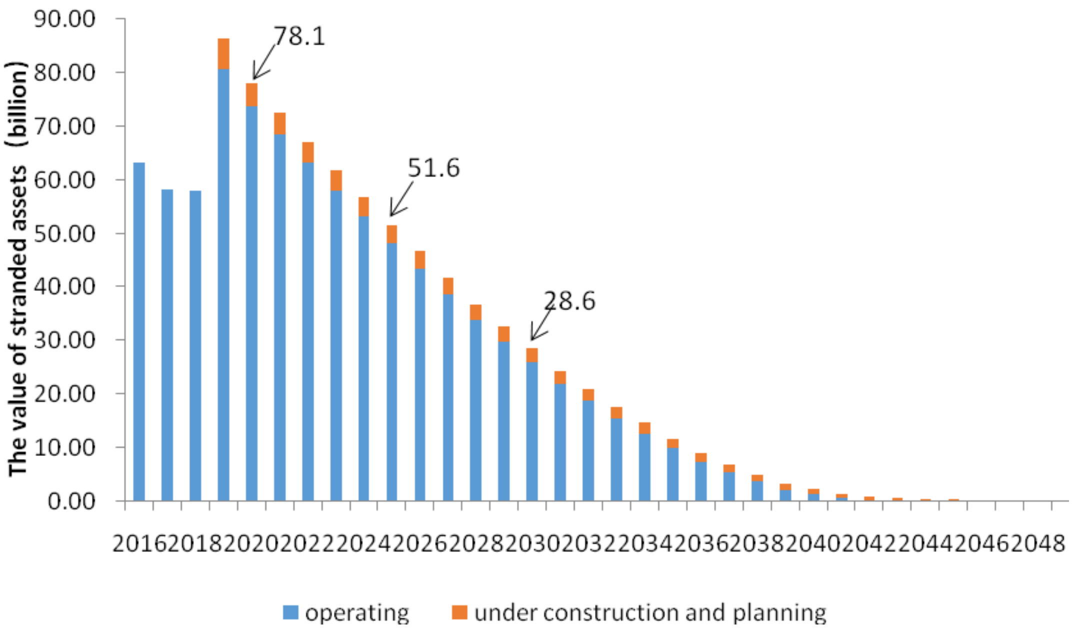
Figure 3 The value of stranded assets in Jilin under Scenario 1



(Note: Since NEA had released three warning files (hard brake)on coal power construction successively in March 2016 and then updated the stringency in October to control new construction, we assume that the progress of new projects in Jilin is much slower than planned in Scenario 1.)

In Scenario 2, half of the new coal projects (under construction and planning), or 3500 MW would be built by 2019. A small fraction (700 MW) would be commissioned by 2018, while most would be commissioned by 2019. Starting with 9643 MW stranded capacity at 2018, in the baseline situation—the most extreme case, where coal power is decommissioned now—the total impairment charges would be RMB86.3 billion in 2019, RMB34.1 billion more than in Scenario 1 at the same year, largely because new installed capacity led to 3500 MW more stranded assets in the existing capacity. In the 5-year window (2020), total asset stranding charges are RMB78.1 billion. The stranding charges in the 10-year window (2025) are RMB51.6 billion. Finally, the 15-year scenario estimates total asset stranding charges to be RMB 28.6 billion. The extensive commission of new capacity in 2019 is the main factor contributing to the increase of stranded charges.

Figure 4 The value of stranded assets in Jilin under Scenario 2



In Scenario 3, all the new projects under construction and planning would be commissioned by 2019, and there would be new approval after 2019. In the most extreme situation, where all the excess capacity was to be decommissioned in 2019, including some new plants that have just been put into operation, the stranding charges were as high as RMB 110.1 billion. The stranding charges at the 5-year, 10-year and 15-year windows are RMB99.2, 66.1, and 37.5 billion, respectively.

A comparison among three scenarios clearly reveals that strict control of the scale of new installation can effectively avoid the consequence of larger-scale stranding assets and the corresponding loss. For a province such as Jilin, with serious oversupply and weak demand growth accompanied by great uncertainty and huge renewable substitution potential, earlier discontinuation of new coal power projects are halted will reduce the risks of avoidable stranding assets correspondingly.

Figure 5 The scale of stranded coal assets in Jilin under Scenario 3

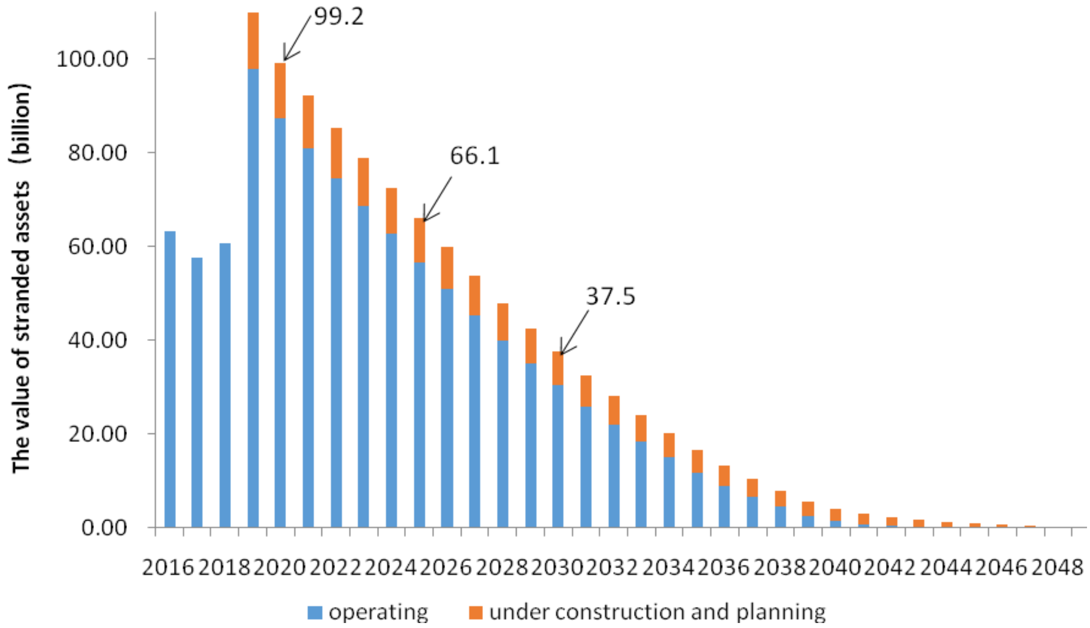


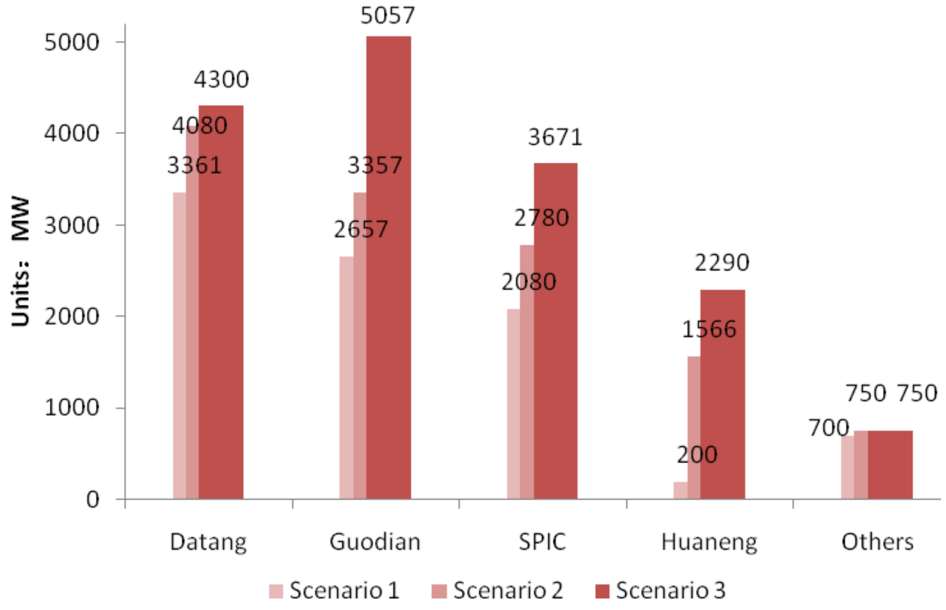
Table 4 Estimate of stranding asset charges in Jilin under different scenarios

Scenario	Stranding year	Existing capacity	New capacity	Total (RMB billion)
1	2020	46.2	0	46.2
	2025	29.1	0	29.1
	2030	14.9	0	14.9
2	2020	73.8	4.3	78.1
	2025	48.1	3.5	56.1
	2030	25.9	2.7	28.6
3	2020	87.5	11.7	99.2
	2025	56.6	9.5	66.1
	2030	30.4	7.1	37.5

The utilities' stranded assets

The top four generation utilities, Guodian, Huaneng, China Power Investment, and Datang, will be confronted with most of the stranded assets in Jilin. As the coal fleet of the Guodian Group is ageing and smaller in unit size, Guodian will experience higher risk in stranded capacity. However, as China Power Investment has the most new capacity under construction, it will face more stranded assets in Scenario 3. Taking 2020 as the year of stranding, Guodian, Huaneng, China Power Investment, and Datang will have stranded assets valued at RMB 23.09, 20.08, 27.66, and 22.11 billion respectively. It is imperative that generation utilities curb new coal projects as quickly as possible to avoid the tremendous loss incurred by stranded assets in future.

Figure 6 The stranded assets of major power generation groups in Jilin Province under different scenarios



The impacts of stranded assets

The stranded assets will also lead to serious issues in power system operation and, in particular, the integration of renewable energy. In the present institutional arrangement, even with serious excess capacity, low-efficiency capacity will not exit the market. Rather, all the generation units, both advanced and retrograde, will operate at lower load factors, and the operational efficiency of the power system will be reduced. Curtailment will become even more serious for renewable energy, because, in some situations, the output of coal units under minimum capacity is enough to meet up with system load, or the operational inflexibility of coal power reduces the ramping capability of the system.

Policy implications

Exert hard control over new projects. Stop all new coal power projects under construction and in planning. According to construction progress, suspend the projects that can be terminated and postpone those that cannot be terminated. Cancel all planned projects. Exerting the strictest control over new projects, try to ensure that coal power will not compete with renewables in new demand.

Compress existing coal capacity. Implement a strict decommission policy. Decommission all units that have been serving for 30 years and longer in addition to those units that have served more than 25 years but cannot meet the new energy efficiency and emission performance standards through retrofitting. With this policy, at least 3000 MW ageing coal capacity should be retired during the 13th FYP period.

Conduct flexibility retrofitting in existing units. According to the grid integration requirement of wind development, conduct flexibility retrofitting in 3000 MW of the existing coal fleet (including CHP units). Meanwhile, retrofit 1000 MW extract condensing CHP units into back-pressure CHP units. In total, retrofitting can provide at least 2000 MW of fast ramping flexibility while cutting the system minimum output during the heating season effectively. It is suggested that the Jilin provincial government and the NEA will continue to implement the fiscal subsidy policy on phase-out small and inefficient coal power from 11th FYP and establish a special fund (with input from structural adjustment fund) to support the closure and retrofitting of existing coal capacity.

Curtail annual output plans. According to the requirements on deregulation of annual production plans, all these new commissioned coal units will not be given any output plan. Meanwhile, gradually curtail the share of annual plans for existing units.

Develop power market actively. The ancillary service market in the Northeast power grid has been initiated in 2016. With the ancillary service market to properly compensate for the provision of ancillary and flexibility services by coal units, some coal units will be gradually transformed from serving base load to providing flexibility service in the power market. The benefits are twofold. On the one hand, new sources of market revenue can be provided to partly offset the loss due to excess capacity and to smooth the exit process. On the other hand, the vital flexibility service can facilitate the large-scale integration of renewable energy into the power system. Meanwhile, promote the development of a spot market with a firm advance of transmission and distribution pricing reform. The target is to establish an integrated power market system consisting of a forward market and a spot market made up of day-ahead, intra-day, and ancillary service markets.

Employ green financing measures to facilitate green investment. On financial policy, the provincial government can also work closely with the central bank to explore innovative green financing measures. Policies including promoting a green fund, a green guarantee, financial discount for renewable energy projects/companies, and conducting pressure testing for coal power projects/companies can be employed to facilitate the renewable energy transition in Jilin province.

1. The electric power development at Jilin: status quo and outlook

Jinlin power grid is located at the middle of the Northeast power grid and covers nine power supply regions, including Changchun, Jilin, Siping, Liaoyuan, Tonghua, Baishan, Baicheng, Songyuan, and Yanbian.[4] Since the 2002 power sector reform, Jilin Provincial Power Company Limited has been responsible for the construction and operation of transmission and distribution networks in this province, serving a total of 27.39 million people over a power supply area of 187,400 square kilometres. More than a dozen power generators operate in this province, and the top four of these companies (Datang, Guodian, Huaneng, and China Power Investment) account for most of the market share. To be specific, coal power accounts for 83% of the total power supply in this province, while the top four companies account for more than 96% of coal power market. During the 12th FYP period, stable growth in the power grid and power sources has satisfied social and economic development in this province.

The status quo of the power sector in Jilin

Weak electricity demand growth

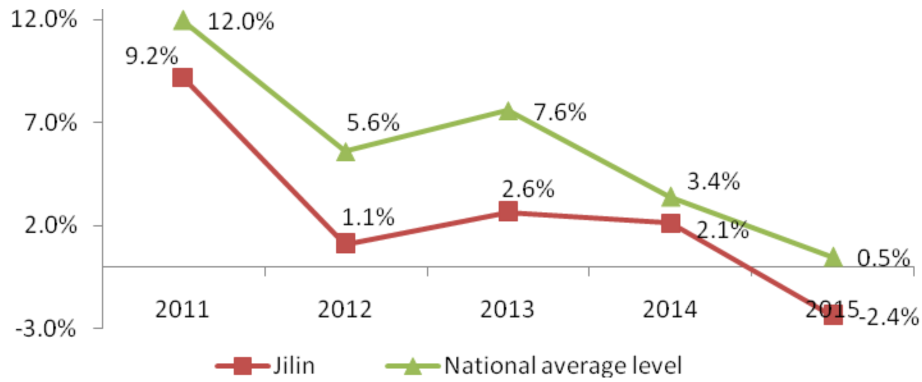
With the advent of the new normal of the Chinese economy, the growth of total societal electricity consumption has slowed down gradually, from 11.1% annually during the 11th FYP period (2005–2010) to 5.7% during the 12th FYP period (2011–2015).[18]In 2015, an unusual low growth rate of 0.5% was recorded. Although the trend in electricity demand in Jilin was roughly the same as that of the national total, the growth in electricity consumption in Jilin province was weaker than the national average. Electricity consumption grew by 8.83% annually during the 11th FYP period[4], but the annual growth dropped to 2.5% during the 12th FYP period.[18,19]In 2015, the total electricity consumption was 65.2 TWh, down by 2.37% from the 2014 level; this is the first negative growth in recent years.[20]Figure 1-1 provides a comparison of electricity demand growth between Jilin and the National total during the 12th FYP period.

[18]China Electricity Council, “Schedule of Basic Data in Power Statistics of 2015”,<2015 年电力统计基本数据一览表> , 2016, http://www.cec.org.cn/guihuayutongji/tongjxinxi/niandushuju/2016-09-22/158761.html

[19]China Electricity Council, “Compilation of Statistical Data for Electric Power Industry in 2011”,<二〇一一年电力工业统计资料汇编>, 2012.

[20]Energy Bureau of Jilin Province, " Total electricity consumption in Jilin 2015",2016, http://nyj.jl.gov.cn/gzdt/20160127/564.html

Figure 7 Comparison of electricity demand growth between Jilin and the national total during the 12th FYP period



(Data source: China Electricity Council, "Schedule of Basic Data in Power Statistics of 2011,2021,2013,2014, and 2015")

Deteriorated capacity utilization rate

Under weak demand growth and quick renewable capacity increase, the national average annual utilisation hours of thermal power decreased by 18.46% during the 12th FYP period. For 2015, the utilisation hours for thermal power were 4329 h, the lowest record since 1969.[21] In Jilin province, the utilisation hours for thermal power was merely 3326 h, which made Jilin one of the six provinces with annual utilisation hours of thermal power lower than 3500 h. For wind power, the annual utilisation hours in Jilin was 1430 h, much lower than the national average of 1728 h in 2015 (Refer to Figure 1-2 for the detail).[13]

Figure 8 Comparison of thermal and wind power utilisation hours between Jilin and the national average during the 12th FYP period

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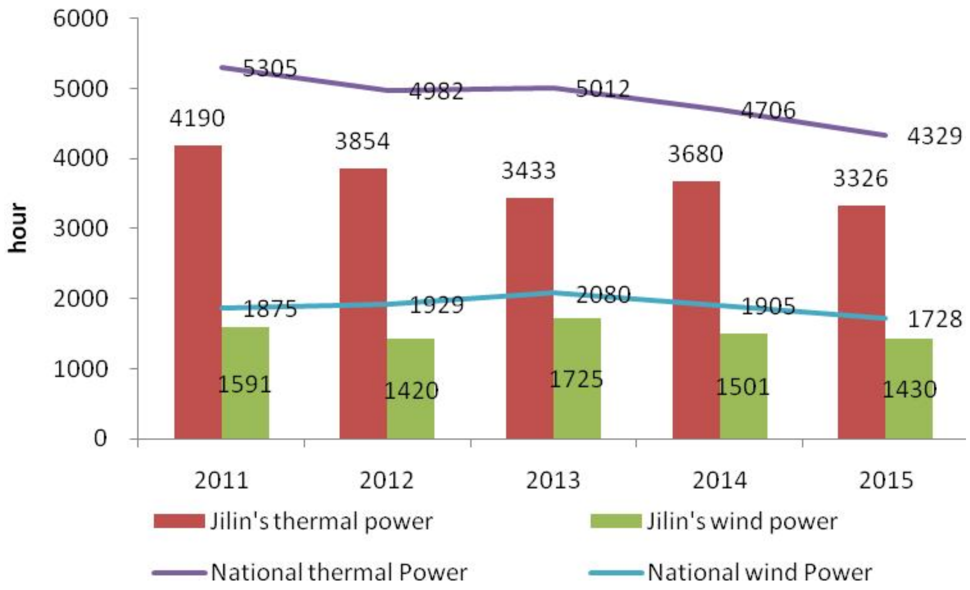
[21]Greenpeace, "Study on Economics of Coal-fired Power Generation Projects in China", <中国燃煤发电项目的经济性研究>, 2016.



(Data source: National Energy Administration, "Average Utilisation hours Situation of Power Generation Units of 6,000 kW or More in China in 2011,2012,2013,2014 and 2015)

Quick capacity increase and overcapacity

By the end of 2015, the total generation capacity installed in Jilin reached 27,185 MW, with 17,830 MW coal power (65.5%),[2] 3790 MW hydropower (13.9%), 4920 MW wind power (18.1%), and 6450 MW made up of solar (0.3%) and others (2.1%).[3]

According to the power development plan of Jilin Power Company,[4] an anticipated 11,021 MW new generation capacity will be added, and the total capacity will reach 38,536 MW by the end of 13th FYP period. To be specific, thermal power will reach 20,943 MW, accounting for 54.35% of total capacity, hydropower will be 4800 MW, accounting for 12.64%, wind power will be 9712 MW, accounting for 25.2%, solar PV will be 726 MW, accounting for 1.88%, pumped storage hydropower will reach 1700 MW, accounting for 4.4%, and biomass and others will reach 381 MW, accounting for 1%. Meanwhile, according to the regulation and control policy for coal power by National Energy Administration (NEA), it is planned to decommission roughly 400 MW small and inefficient coal power in Jilin province during the 13th FYP period. Accordingly, the features of generation capacity growth in Jilin province during the 13th FYP period can be summarised as a slow-down in coal power growth and rapid growth in wind power.

Table 5 Power generation planning of Jilin power grid during the 13th FYP period

Unit: MW	2016	2017	2018	2019	2020

Regular hydropower	3471.9	3570.4	4200.4	4800.4	4800.4
Pumped storage	300	300	300	300	1700
Coal	18543.5	19093.5	19843.5	19843.5	20943.5
Gas	0	0	0	0	0
Nuclear	0	0	0	0	0
Wind	6692.8	8538.8	9212.3	9712.3	9712.3
Waste	123	153	228	243	273
Biomass and others	231.5	321.5	381.5	381.5	381.5
PV	300.9	435.9	560.9	655.9	725.9
Total	29663.6	32413.1	34726.6	35936.6	38536.6

(Data source: Economic and Technical Research Institute of State Grid Jilin Province Electric Power Supply Company, "Report on the development planning of Jilin power grid in 13th FYP period", 2014)

Electricity demand scenarios and outlook

Demand growth scenarios

Status analysis has identified weak electricity demand growth in Jilin because of adjustment in economic output structure and de-capacity in energy-intensive industry, as well as much slower demand growth compared with the national average. From the perspective of electricity consumption structure, secondary industry in Jilin still accounts for most (64%)of total consumption,[20] but the share has been declining. The share of service industry and household consumption is increasing, but their contribution to overall demand growth is marginal because of the small base.

According to existing studies, national electricity demand growth will very likely range between 4.2% and 4.9% annually during the 13th FYP period.[22]The recently issued power planning for the 13th FYP predicts a similar range, of 3.6%–4.8%.[23].In this report, three

[22]Polaris power net, "How much coal power is needed in 13th FYP?", 2016.

[23]National Energy Administration, "The electric power development planning in 13th FYP period", <电力发展‘十三五’规划>, 2016.

scenarios for electricity demand growth in Jilin province are provided. Scenario 1 assumes a weak annual growth of 2% because of weak economic growth. Under this scenario, the gap in growth rate with the national average will continue. Scenario 2 assumes moderate improvement in economic growth because of the effect of the Northeast Revitalisation Plan. Under this scenario, the growth rate during the 13th FYP will be 3.5%, and the gap with the national average will narrow. Scenario 3 assumes a more positive effect of economic growth in Jilin, under which electricity demand will grow at 4.5% annually, largely in step with the national average. In this report, considering the actual economic situation, we use Scenario 2 as the preferred scenario.

Scenarios of generation capacity increase

To cope with overcapacity, NEA issued a policy document to highlight the construction risks involved in coal power in thirty-three provincial grid regions for the coming 3 years.[14] For the Jilin grid, 'red' alerts were given for both generation resource adequacy indicators and construction and planning risk indicators, implying that no new projects should be approved and that the projects under construction should be suspended. However, the credibility of the related regulation policy is problematic, and the actual effect is subject to further confirmation. On the other hand, Jilin is endowed with rich wind resources, with a wind energy density of 60–70 watts per square meter and a theoretical wind potential of 692 TWh annually. With a steady wind speed and appropriate terrain, Jilin is suitable for construction of large-scale wind farms. Hence, there was rapid development of wind power project installation in Jilin from 2009 to 2013.[4] However, due to serious excess supply, the wind power project curtailment rate has been as high as 30% in the past 2 years. Therefore, in the past 3 years, no new wind power project had been approved in Jilin.[12] In a word, the issue of excess supply is very serious in Jilin's power sector.

Based upon the coal power and renewable energy development policy documents by NEA and the National Development and Reform Commission (NDRC),[24]we construct the likely scenarios of generation capacity increase in Jilin during the 13th FYP as follows. For coal power, three scenarios are provided. For the High growth scenario, it is assumed that all the projects planned and under construction would be commissioned. The Medium scenario assumes that only half of the new projects would be commissioned while the Low growth scenario assumes zero growth of coal power during the 13th FYP. For wind power, two scenarios are provided in this report. The High scenario assumes a growth rate of 14% annually, according to the plan by Jilin Power Company, while the Low scenario assumes 7%

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[24]National Energy Administration, "Notice on further regulation and control of coal power planning and construction", <关于进一步调控煤电规划建设的通知>, 2016.

annual growth. For other generation resources, including hydropower, and PV, etc., we adopt the planning numbers declared by Jilin Power Company. In sum, we use the scenario of zero coal power growth and low wind power growth as the Policy scenario in our further analysis.

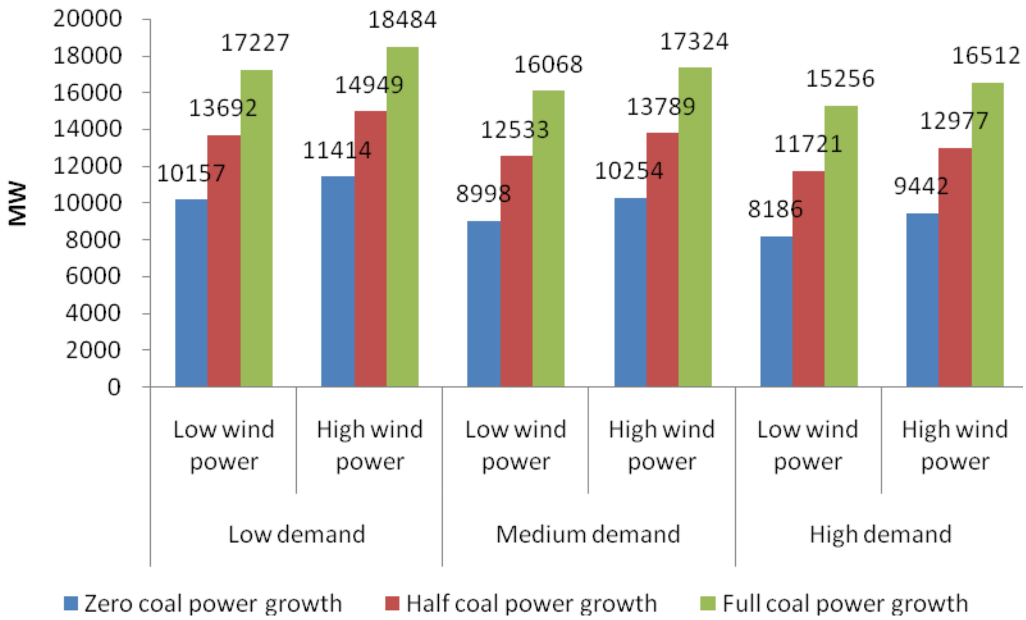
The decommission and shut-down of coal power

Under the de-capacity policy, as well as the stricter environment constraints, some ageing or highly pollutant coal power plants in Jilin have either been decommissioned or shut down in recent years. In 2014, a total of 825.5 MW coal power was decommissioned.[4] In 2016, soon after the publication of the national coal power regulation and control policy, the Energy Bureau of Jilin province issued its regulation policy and declared its intention to shut down 900MW coal power plants.[5] In addition, according to the policy document that NEA issued on 23rd September 2016, three new coal power projects in Jilin province will be cancelled because they do not conform to the approval and construction conditions.[6]

Quantifying excess scale of coal power

Based upon the above setup of electricity demand scenarios, we use a power generation capacity expansion model to quantify the rational scale of coal power, with a priority of renewable energy development. The excess capacity of coal power by 2020 can then be estimated under different scenario settings (Figure 1-3). We find that the excess will range between 8186 MW and 18,484 MW, subject to different assumptions. For the Policy scenario (moderate demand growth, low wind power growth, and zero coal power growth), excess capacity of coal power in Jilin will be about 9000 MW by 2020.

Figure 9 Estimation of excess coal power capacity under different scenarios by 2020



2. The environment of coal power development

Coal power holds a dominant position in the power generation mix of Jilin, accounting for more than 60% in total capacity and 80% in total generation.[4] Although renewable energy has developed quickly in recent years, because of resource endowment, a huge profit margin, and huge tax contribution to local governments, coal power maintains high growth in China. On the other hand, the utilisation of coal capacity is deteriorating by a large extent due to weak demand growth, while the future of coal power is always put into question by stricter environment constraints and ongoing market reform. Thus, we summarise the environment for coal power development in Jilin province as follows.

Stricter environment constraints and higher CO2 abatement pressure

With the aggravation of atmospheric pollution in most regions, pollution prevention and control has been given unprecedented emphasis in China. Since 1st January, 2016, the newly revised Atmospheric Pollution Prevention Law has been formally implemented. This is the first legislation to confirm clean and renewable resource priority in power dispatch, and it represents a heavy blow to the convention of power system operation and pricing mechanism based upon coal power. Furthermore, in relation to pollution control in coal power plants, according to the Work Plan on Full Implementation of Ultra-low Emission and Energy Conservation Retrofitting in Coal Power Plants by NEA, NDRC and MOEP (Ministry of Environment Protection), the East, Central and West regions are required to complete retrofitting by 2017, 2018, and 2020, respectively.[25] Although coal plants can receive price subsidies for ultra-low emission retrofitting, they will face heavy pressure regarding end-of-pipe pollutant control equipment investment and rising pollutant discharge fees. Moreover, in June 2015, China submitted its NDC (Nationally Determined Contribution) to the United Nations and committed to peak its greenhouse gas (GHG) emissions by 2030 and as early as possible. The 13th FYP period is the critical implementation stage of climate policy in China, and the national carbon trade system, which will be initiated in 2017, will bring forth carbon costs to coal power generation.

Jilin, which is the old industrial base in China, has made a big contribution to the industrialisation of the country. However, in recent years, the side effects of extensive growth, in particular resource shortage, environmental deterioration, and persistent and severe haze, have impeded social and economic development in this province. In response, Jilin provincial government has accelerated the pace at which it is curbing pollution issues. In June 2016, a clean air action plan (2016–2020)[8]was issued by Jilin provincial government. The plan made a firm commitment to capping coal consumption and accelerating energy mix adjustment while defining the main objectives and the timetable of atmospheric pollution prevention and control. In a policy document on the Coordinated Development of the Power Sector in Northeast China, NEA also requires completion of ultra-low emission retrofitting of coal power plants of 300 MW and above in the Northeast regions by 2018.[9] In Jilin, 12,000 MW coal capacity is 300 MW and above. As the emission performance of these plants is generally much higher than the national average, they will incur expensive retrofitting expenditure in complying with this strict emission standard.

Low carbon transition and squeezed coal power market

[25]Ministry of Environmental Protection, National Development and Reform Commission and National Energy Administration, "the full implementation of ultra low emission and energy saving transformation of coal-fired power plants", <全面实施燃煤电厂超低排放和节能改造工作方案>, 2015.

Since 2013, capping primary consumption, checking the growth of coal consumption, and accelerating non-fossil development have become central to national energy policy in China. The National Climate Change Program (2014–2020)[10] required that non-fossil energy should account for no less than 15% of primary energy by 2020. According to the recently submitted NDC file, non-fossil energy will contribute 20% of primary energy by 2030. For the electric power sector, it is imperative to optimise the energy structure. On one hand, clean coal power is necessary for capping coal use in this sector. On the other hand, it is important to accelerate clean energy transition, especially the development of wind and solar power. At the national level, specific renewable energy targets have been stipulated, including at least 200 GW wind capacity and grid parity with coal power, and 100 GW solar power capacity and grid parity with retail prices by 2020.[26]Under the overall transition to a clean and renewable energy system, the market space for coal power will be squeezed in China.

Jilin is endowed with rich wind resources and is among the nine 10 GW wind power bases. Until 21st June, 2016, with the commission of Guodian Jingang wind farm, the grid-connected wind power reached 5000 MW in this province.[27] Though confronted with wind power curtailment, under the overall trend of low-carbon transition, governments at all levels have introduced a series of policies promoting renewable energy development. In a policy document issued by Jilin provincial government ion April 2016, measures, such as generation rights trading, have been put forward to facilitate the local consumption of wind power. At the national level, a Chinese version renewable portfolio standard (RPS) had been proposed by NEA. This RPS requires that non-hydropower renewable generation should make up 9% of the power generation of all generation companies (with the exemption of specialised non-fossil energy companies) by 2020.[11] As one of the leading renewable energy provinces, Jilin is required to generate more than 13% renewable energy in its overall generation. The information is very clear: in this province, the market space for coal power will be largely squeezed in the future.

Overcapacity and phase-out stress of coal power

Under conditions of oversupply, whilst tightening environmental constraints, phase-out of backward coal power capacity has become the policy keynote of NEA. Since 12th FYP period,

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[26]The State Council, "Strategic Action Plan for Energy Development (2014–2020)", <能源发展战略行动计划（2014-2020年）>, 2014.

[27]Polaris wind power net, "Rapid growth of wind power capacity in Jilin to 5000mw", 2016.

28,000 MW of inefficient and heavy pollutant coal power has been closed, exceeding the declared target of 20,000 MW,[28]an explicit signal that the government will strengthen the shut-down of backward capacity in the future. In 2016, NEA and NDRC have issued a series of policy documents on coal power that constitute a policy package to tackle the potential risks of excess capacity and guide the orderly development of coal power. According to the newly released 13th FYP Electric Power Development Planning, at least another 20,000 MW of inefficient coal power will be closed in the coming 5 years.

Even since 2014, with the increasing economic downturn pressure, a severe oversupply of electric power has emerged in the Northeast region. In particular, the annual utilisation hours of generation units in the Northeast region have continually ranked last in China. Data from the Jilin Energy Bureau can partly reveal the main problems. Firstly, there is serious oversupply, with more than 40 TWh excess generation capacity. Secondly, the generation capacity of combined heat and power (CHP) units reaches 131,48.4 MW, which accounts for 74% of the coal fleet and is 8000 MW larger than the minimum system load and 4000 MW larger than the maximum system load.[12] Lastly, by the end of 2015, the total coal power capacity in Jilin was 18,000 MW, whereas the annual utilisation hours were merely 3362h, much lower than the national average.[13] As a province with red alerts in capacity adequacy indicators and planning and construction indicators, Jilin's coal-power sector will face heavy phase-out pressure.

Power sector reform and its impact on coal power

In March 2015, the Opinion on Further Deepening Power Sector Reform (the No.9 File)[29]was released, marking the launch of a new round of power sector reform. According to the No. 9 File, energy efficiency, energy conservation and emission abatement, renewable energy, and distributed energy will be the priority direction of power sector development. Furthermore, independent power exchange will be organised, while a fair and formal trading platform will be established. In particular, the current power generation and consumption planning will be curtailed gradually, while new industrial customers and newly commissioned generators will be required to directly participate in market trade. Accordingly, on 13th July, 2016, the Bureau of Economy Operation Regulation affiliated with NDRC released an exposure draft file on the

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[28]National Development and Reform Commission and National Energy Administration, "Notice on Further Eliminating backward production capacity of coal power industry",<关于进一步做好煤电行业淘汰落后产能工作的通知>, 2016.

[29]The State Council, "Opinions on Further Deepening the Power System Reformation", <关于进一步深化电力体制改革的若干意见>, 2015.

Orderly Deregulation of Power Generation and Consumption Planning,[30] stipulating the specific market reform roadmap for coal power. According to this policy design, during a transitional period lasting 3–5 years, the total generation will be allocated into two parts, a planned portion, which will be gradually reduced, and a new market trade portion which will be gradually expanded. In addition, all the newly commissioned coal power plants after 15th March 2017 will no longer be given any planned generation hour. All these measures will bring forth fierce price competition for surviving coal power plants while constraining the market space for new coal power plants under construction.

With the establishment of provincial power exchanges, coal power has experienced a market shock in all provinces. For example, in Guizhou, the implementation of market trade has reduced the retail price for industrial customers by 0.12 RMB/KWh, which will cut down the revenue of generation by at least 100 million RMB.[31]Jilin is not the pilot province of power sector reform and lags behind other leading provinces, such as Guizhou and Guangdong, in advancing the reform. However, on 13th April, 2016, Jilin established its power exchange. In the future, the power exchange will play a critical role in both promoting the scale-up and efficient utilisation of renewable energy and facilitating the low-carbon transition. It is unquestionable that market reform will inflict a drastic shock on coal-power in Jilin, which has serious excess capacity.

3. Quantification of stranded coal power assets and risks analysis

Stranded assets can be defined either as assets that suffer from unanticipated or premature write-offs or downward revaluations, or as assets that are converted to liabilities as a result of social norms (behaviour), resource landscape (water / coal), clean technology costs (solar /

[30]National Development and Reform Commission and National Energy Administration, “Orderly Deregulation of Power Generation and Consumption Planning (exposure draft file)”, <关于有序放开发用电计划工作的通知（征求意见稿）>, 2016.

[31]Polaris transmission and distribution power net, “Guizhou promoted the implementation of direct trading of electricity to release the reform dividend of supply side ", 2016, http://shupeidian.bjx.com.cn/news/20160816/762682.shtml

wind), regulation (new policy), climate change (environmental challenges), and litigation and liability (cost /responsibility of damage).[1]

The stranded assets of the power sector can be defined as assets for which the revenue has failed to achieve the desired value under the competitive and external environments. This report identifies and analyses the factors that may cause stranded coal power assets in Jilin Province and conducts quantitative research on stranded assets.

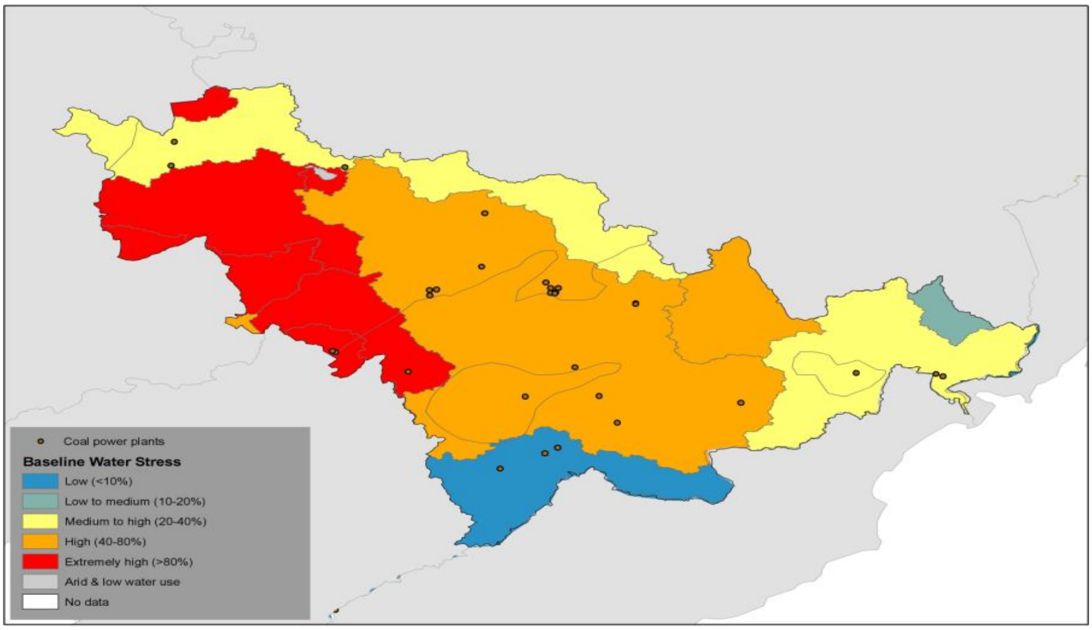
Identification and influence of stranded factors

Coal-fired generating units are exposed to varying degrees of stranding risk due to overcapacity, non-fossil energy substitution, energy efficiency and environmental improvements, and the implementation of carbon markets. Based on the assumptions of national and local level indicators,[17] this report incorporates and simplifies some of the indicators, and identifies the stranded factors of coal-fired generating units from both the regional risk and the generator's own risk. A five-grade scoring system is used, with 5 standing for the highest risk, 4 for higher risk, 3 for medium risk, 2 for lower risk, and 1 for the lowest risk.

Local Risk Factors:

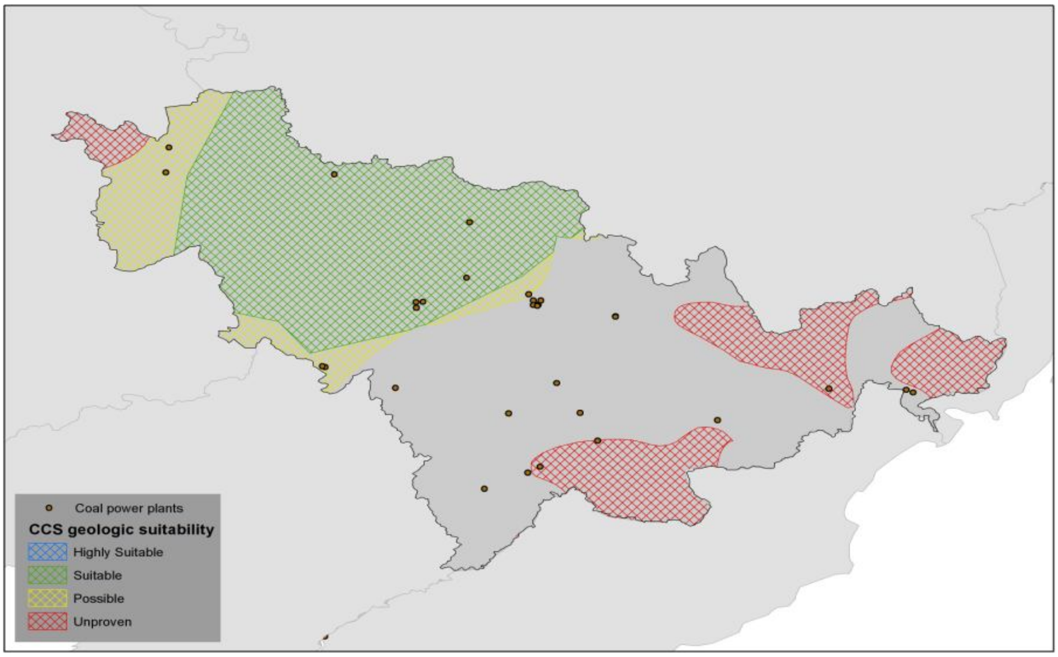
BWS: Water-cooled coal power units need to consume large amounts of water in cooling process, so local water resources will affect the operation of the unit. If the water stress in the area power stations are located in is higher, the units will be at higher stranded risk in the future. Based on the BWS map of Jilin, we scored each unit according to the area that units are situated in. The greater the water pressure, the higher the score.

Figure 10 Baseline Water stress map of Jilin



CCS: Under the influence of environmental standards and policies, eligible coal-fired power units will accept CCS technology transformation to avoid higher stranded risk in the future. Based on the distance between the location of power stations and CCS geological suitability areas in Jilin, we scored each unit according to the location of the units. The further the distance, the higher the score.

Figure 11 CCS geologic suitability map of Jilin



Heat Stress: Jilin province is located in China's Northeast region where the temperature is relatively low at most of the time. Physical climate change will exacerbate heat stress on power stations, and higher ambient temperatures will decrease the unit efficiency and exacerbate water stress to pose stranded risks. Based on the heat-stress map of Jilin, we scored units according to the location of the units. The higher the heat stress, the higher the score.

Figure 12Heat-Stress map of Jilin

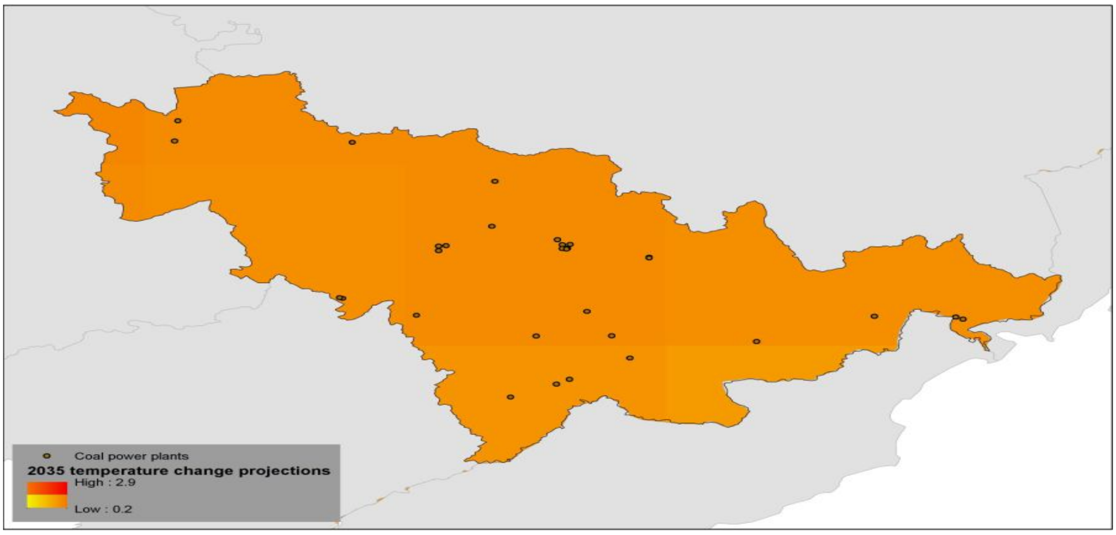
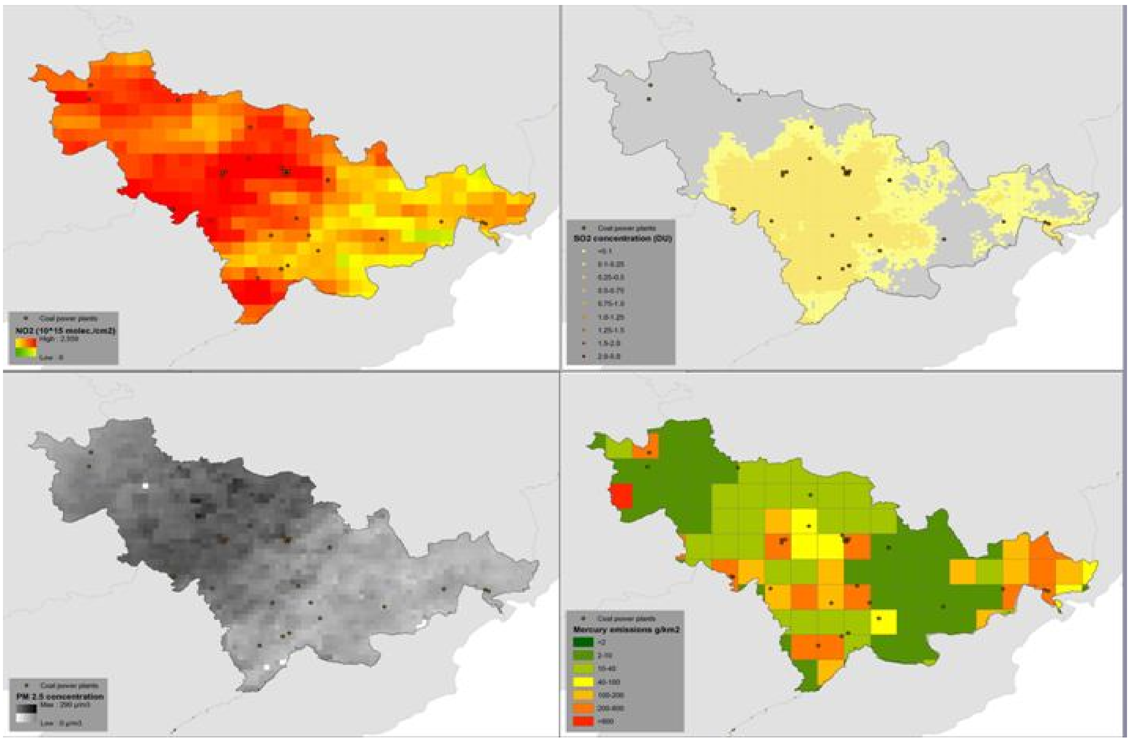


Figure 13 Pollutant intensity map of Jilin



Pollutant index (SO_2, NO_2, $PM_{2.5}$, Hg, etc.): If the atmospheric pollution is serious in the region where coal-fired units are situated, the stranded risk will be higher. Based on the pollutant intensity map and the correlation between the intensity of air pollutants and the concentration of ground $PM_{2.5}$ in Jilin, we scored units according to the location of the units. The higher the pollutant concentration, the higher the score.

Generator Risk Factors:

Operating life: The operating life of coal-fired units is generally 30 years in China, and unit performance and efficiency will go down over time. The longer the unit operates, the greater is the stranded risk.

Unit capacity: A large capacity unit generally performs better and is in a better position to meet the requirements of energy-saving and emission reduction development in future. Smaller units will face higher stranded risk in the case of excess capacity.

Coal consumption for generation: Different types of units have corresponding design standards of heat rate for power supply. NEA released "The Energy saving and Emission Abatement Plan of Upgrading and Transforming Coal Power in China (2014–2020)"[32] document in 2014 to accelerate the revolution in energy production and consumption and further enhance efficient and clean coal power development. We scored each unit according to the gap between actual coal consumption level and the advanced level declared by the document. The greater the gap, the higher the score.

SO2, NO2 and PM2.5 emissions: Increasingly stringent environmental standards and emission reduction policies are placing ever-stricter requirements for coal-fired units in terms of pollutants emission performance (SO_2, NO_2 and $PM_{2.5}$), and units with higher pollutant emissions will face greater risk in the future. We scored each unit according to the gap between the actual pollutants emission performance of units and the ultra-low emissions standards. The greater the gap, the higher the score.

After identifying the factors contributing to the stranded risk of the coal power unit, we scored each stranded risk factor and ranked the risk of being stranded for all coal power units in Jilin. Regional risk and generator risk scores were converted into percentile scores with weights of 60% and 40%, respectively. From the ranking results, the unit risk score ranges

[32] National Energy Administration, “The Energy saving and Emission abatement Plan of Upgrading and Transforming Coal Power in China (2014-2020)”, <煤电节能减排升级与改造行动计划（2014-2020 年）>, 2014.

from 46 points to94 points. As environmental pollution in most parts of Jilin province is serious, and the carbon capture and storage sites are concentrated, the difference was mainly due to the generator risk factors. The results show that the units with high risk scores and top ranks are mostly small-sized units with longer operation life, high heat rate, and poor pollution emission performance. In the situation of low demand and overcapacity, the stranding risk of these units is higher. At the same time, the score sheet will provide a reference for local energy authorities in the elimination of backward coal power capacity and the introduction of disposition policy for stranded assets (see AppendixⅣ and AppendixⅤ)

We can classify the ownership of generation capacity according to statistical data. These show that the State Power Investment Group (a merger of the China Power Investment Group and State Nuclear Power Technology Company), Guodian Group, Datang Group, and Huaneng Group are the main players in this province, with 9400 MW, 6317 MW, 4960 MW, and 4220 MW capacity installation, respectively, while other generators account for only 3% of total generation capacity (Figure 3-5). For the new projects, Huaneng Group and the State Power Investment Group take the lead, with an expected capacity of commission at 1320 MW and 4350 MW by 2017. For existing capacity, in the top four generation groups, most units are sized between 200 MW and 300 MW, while units sized at and above 600 MW are rare. For other generators, all the capacity consists of units sized below 200 MW (Figure 3-6). Generally speaking, small units have higher stranding risks, due to poorer operational efficiency and emissions performance. In addition, the stranding risks are high because the existing capacity is ageing, with an average service year of 15.

Figure 14 Proportion of coal power capacity of generation group in Jilin

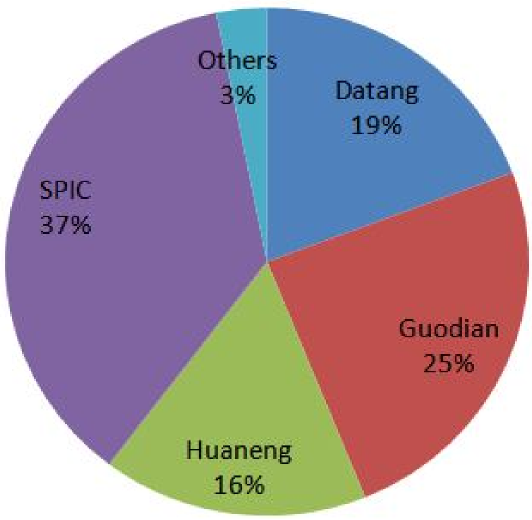


Figure 15 Proportion of the different capacity of major generation groups in Jilin

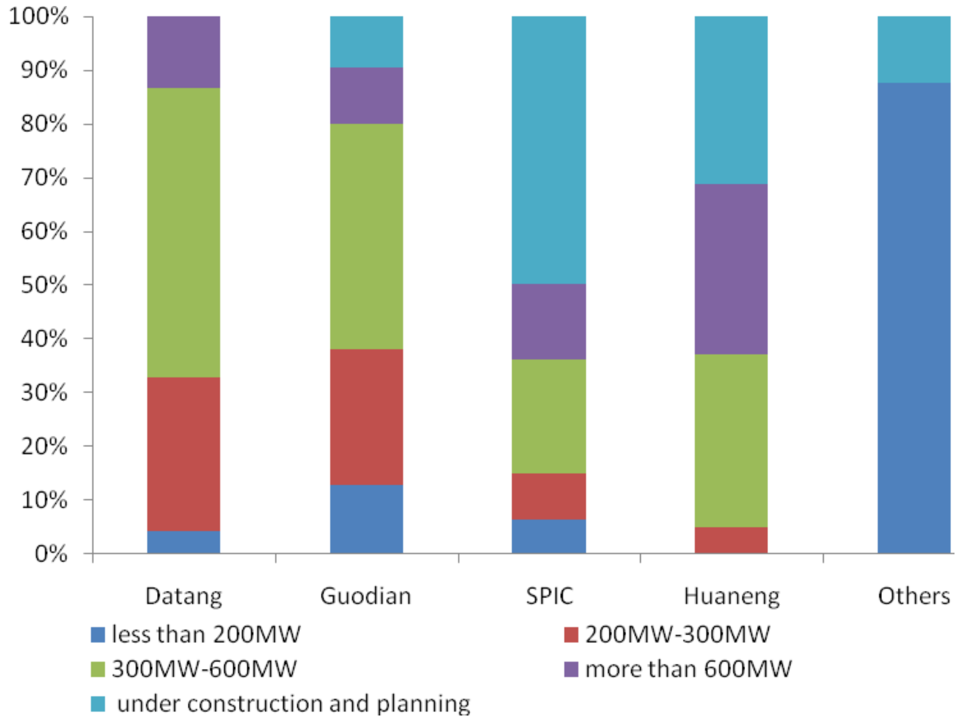
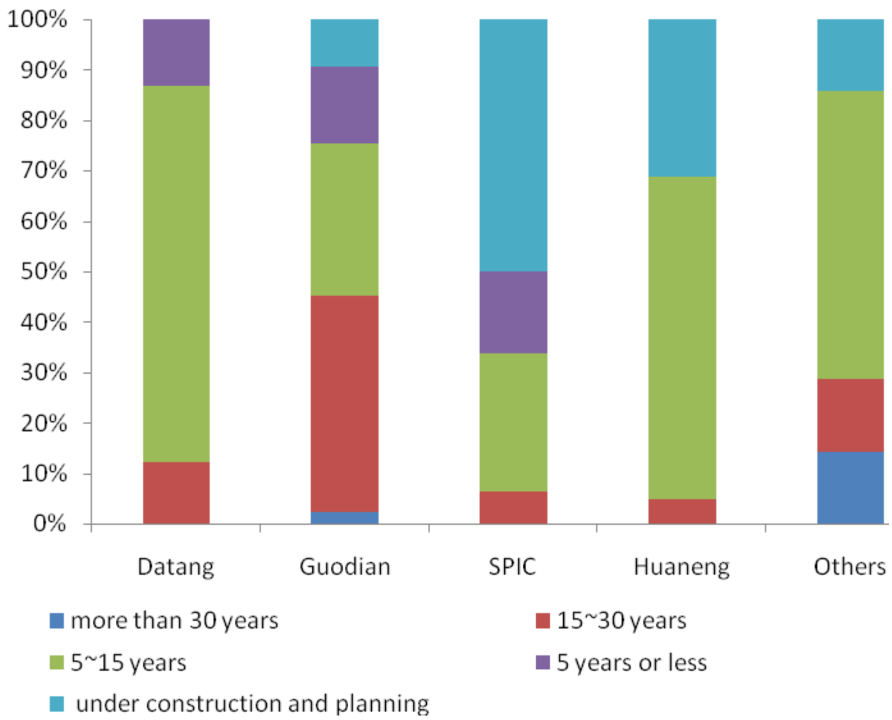


Figure16 Operation life of coal power capacity of major generating groups in Jilin



Two typical coal power plants in Jilin are chosen for case study.

Guodian Longtan power plant is the most susceptible coal power plant to stranded assets risks. In Longtan Power plant, there are seven units with installed capacity at 750 MW; three of these are 50 MW units that have more than 30 years of operation, while two are 100 MW units that were commissioned in 2000. The coal consumption of power generation in Longtan power plant is 334 gce/KWh, while the actual emissions performance of SO_2, NO_x, and dust are much larger than the ultra-low standard. Longtan power plant is located in the middle of Jilin province, which has the highest BSW. Longtan is also far away from an appropriate CCS geological reservoir, which will also lead to higher risk if proper climate policy is in place in the future. Overall, the regional risk and generator risk scores of the 7 units at Longtan power plant are very high, and the stranding risk in the future will be great.

The Siping No. 1 power plant, which was put into operation by the end of the 20^{th} century, has a total capacity of 200 MW, with two 50 MW units and one 100 MW unit. The heat rate of power generation in Siping No.1 plant is as high as 365 gce/KWh, even higher than that of Longtan plant, while the emissions performance is also considerably larger than the national standard. Therefore, Siping No.1 plant has very poor operational efficiency and a bad environment damage profile. However, the cost of retrofitting will add to the cost burden and further reduce the economic performance. The generation company certainly would hope to extend the operational lifetime of this plant for as long as possible with little extra input; however, according to the national energy conservation and ultra-low emissions policy, coal power plants must be retrofitted to reach energy efficiency and emissions performance standards. It is estimated that the investment expenditure of desulphurisation and denitrification retrofitting in existing plants ranges from 250 to 400 RMB/kW. However, for older plants, like Siping No.1, with more than 20 years of operation, the retrofitting expenditure is unlikely to be recovered in the remaining service years. In sum, the risk exposure to stranded assets in Siping No.1 plant and the like is very high.

The risk quantification analysis and case study can reveal several general features of coal plants in Jilin province. The first is that old units make up most of the existing fleet. The oldest unit in service was commissioned in 1959, and many units have served for more than 20 years. The second feature is the poor technology level and performance. Last but not the least important, Jilin suffers serious environmental pollution because of itsheritage as an old industrial base. All these factors will remarkably push up the stranded assets risk in Jilin's coal power.

Quantification of stranded coal assets value

With more than 40 TWh unneeded generation capability in 2016, Jilin province has the most serious oversupply levels in the Northeast region. Oversupply led toa loss of more than one billion RMB for generation companies in Jilin during 2011–2014. In this section, a quantification analysis of stranded coal power assets in this province will be conducted, based upon the collected capacity database. Among the 18,627 MW installed coal capacity, 300 MW–600 MW units account for 45%, units sized below 300 MW account for 34%, and units of 600 MW and above account for only 21%. There are 7070 MW new projects under planning and construction, among which four units are 1000 MW USC. If all the new projects were commissioned, there would be a total of 25,697 MW coal power in Jilin by 2020.[7]

Table 6 The composition of coal power units in Jilin

Category				**Installed**	**Under construction**	**Under planning**	**Total**
		sum	unit	86	2	12	100
			MW	18627	700	6370	25697
Among which	**≥1000 MW**	subtotal	unit	0	0	4	4
			MW	0	0	4000	4000
	600MW–1000MW	subtotal	unit	6	0	2	8
			MW	3980	0	1320	5300
	300MW–600MW	subtotal	unit	25	2	3	30
			MW	8350	700	950	10000
	200MW--300MW	subtotal	unit	20	0	0	20
			MW	4020	0	0	4020
	<200 MW	subtotal	unit	35	0	3	38
			MW	2277	0	100	2377

(Data source: University of Oxford, "Information table of coal power units in Jilin.")

For convenient analysis, we divide coal plants into five categories (Table 3-2). In China we cannot obtain the market value for every power plant because only major generation groups and big independent power producers are publicly listed. In this report, we use the value expectation of a power plant for its entire service life to estimate its stranded value. We define the value of stranded assets as the sum of the initial investment, the investor's return requirement, and the due tax during the service life of a power plant. The underlying assumptions are as follows: 30 years as service life, 20 years for deprecation, with straight-line depreciation method, 15 years for loan repayment, and 5% of initial investment for the residual assets value when decommissioned. In the assessment model, the benchmarking on-grid price for desulphurised and denitrified coal power in Jilin is 0.37 RMB/KWh, and the share of bilateral trading in total generation is set as 10%, with 0.1 RMB/KWh reduction relative to on-grid price.

The 1000 MW USC unit is the most advanced technology in China. If such a unit was stranded when commissioned, the total value loss during its entire service life would reach as high as 22.46 billion RMB. In Jilin province, four 1000 MW USC units will be commissioned by 2019. If fully stranded, the stranded assets value would be around 90 billion RMB, about 1.5 times of the national deficit in renewable energy funds. There are 38 coal units sized below 200 MW with low operational efficiency in Jilin. A phase-out of inefficient coal power will immediately strand these units. The total stranded assets deserve careful attention because of the large quantity of stranded units in this province.

Table 7 Stranded assets estimate for different sized coal units

	Heat rate (Kgce/MWh)	Utilisation (hours)	Build cost (RMB/KW)	Auxiliary rate (%)	Stranded value (100 Million)
≥1000 MW	289	5255	3202	4.28	224.61
600MW–1000MW	311	4868	3400	5.34	104.35
300MW–600MW	313	4355	4100	5.88	39.67
200MW–300MW	331	4157	4300	7.81	19.75
<200MW	334	4810	4500	8.12	14.82

Note: 1. Technical economic parameters are sourced from CEC annual statistical compilation, while the (100%) stranded values of different sized units are estimated by the authors.

2. The value of Stranded assets =years being stranded/30 years*(Initial investment +Expected return of Loan funds+ Expected return of own capital +Taxes)

3. We use project value evaluation model based on cash flow statement to estimate the expected return for a coal power project under prevailing operation conditions. Refer to Appendix Ⅱ and Ⅲ for the process and parameter setting.

In this report, medium demand growth (3.5% annually during the 13th FYP period) is taken as the recommended scenario, under which total electricity consumption will reach 77.4TWh by 2020 in Jilin. Under this scenario, with a power generation capacity expansion model and with the priority of declared renewable energy targets, rational coal power capacity and excess capacity can be quantified. According to the regulation and control policy on coal power by NEA, we assume three scenarios, as follows:

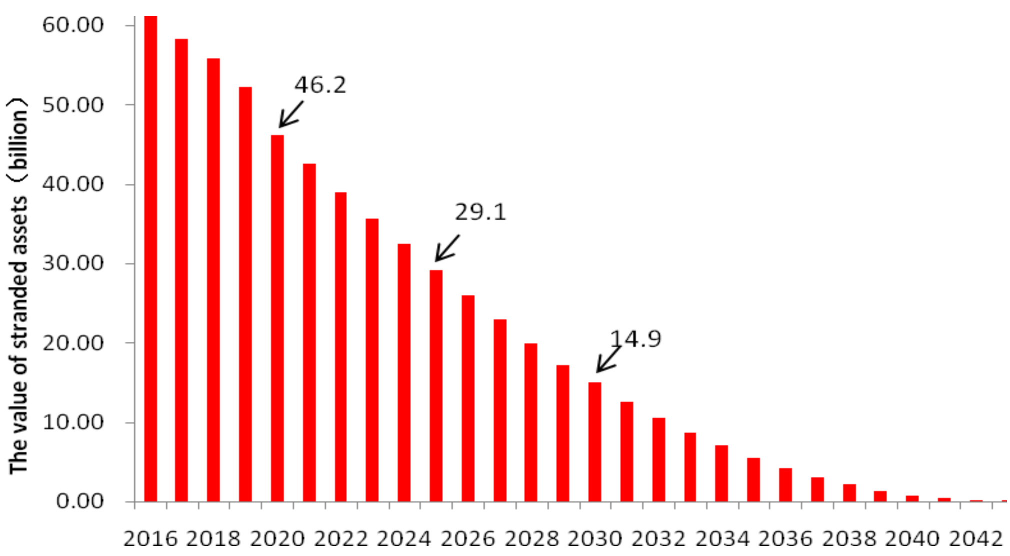
Scenario 1 (optimistic and Policy scenario) assumes that all the new coal projects (including both those under construction and in planning) would be cancelled. In this scenario, there will be no growth in coal capacity during the 13th FYP period in Jilin. According to the power planning model, we can estimate the excess capacity of coal power in different years: 9186 MW in 2016, 9076 MW in 2017, 9293 MW in 2018, 9360 MW in 2019 and 8998 MW in 2020. We further assume that all the new demand since 2020 can be met with renewable energy, so the excess capacity after 2020 will remain unchanged.

Scenario 2 (practical scenario) assumes that half of the new coal projects would be built by 2019, but there would be no new installation after 2020. According to the power planning model, we can estimate the excess capacity of coal power in different years: 9186 MW in 2016, 9076 MW in 2017, 9643 MW in 2018, 12,895 MW in 2019, and 12,533 MW in 2020.

Scenario 3 (pessimistic and Reference scenario) assumes that all the new coal projects would be built by 2019, but there would be no new installation after 2020. According to the power planning model, we can estimate the excess capacity of coal power in different years: 9186 MW in 2016, 9076 MW in 2017, 9993 MW in 2018, 16431 MW in 2019, and 16,068 MW in 2020.

According to the estimate of excess capacity and the scoring of stranded risks, we screen out a long list of the most likely stranded units in Jilin. Then we can estimate the total stranded assets value according to their sizes and residual service years.

Figure 17 the value of stranded assets in Jilin under Scenario 1

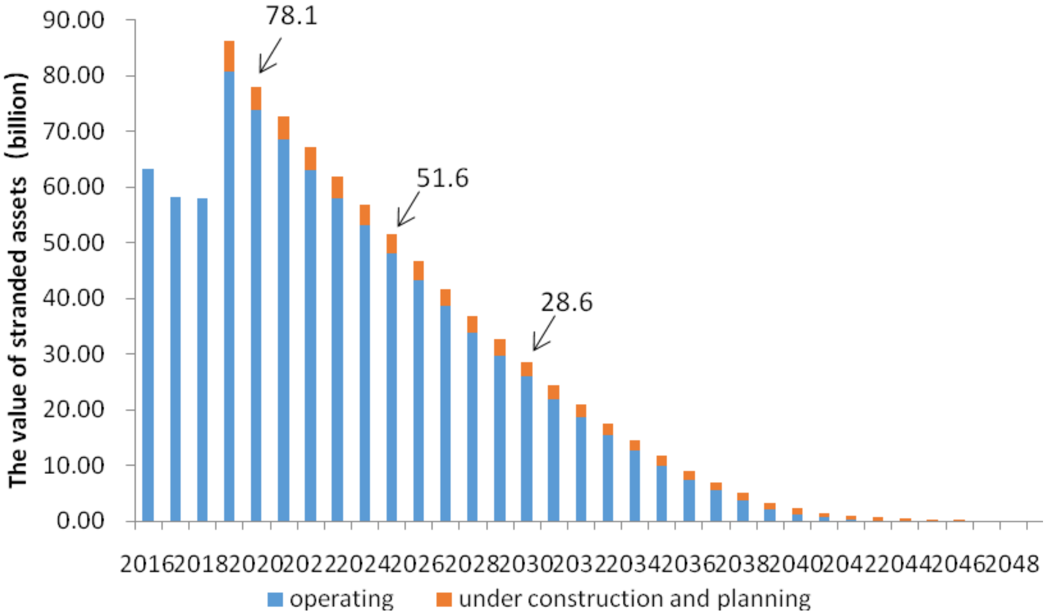


Note: Since NEA released three warning files ('hard brake') on coal power construction successively in March 2016 and then updated the stringency of controlling new construction in October 2016, we assume that the progress of new projects in Jilin is much slower than planned in scenario 1. For simplicity we ignore the sunk cost of the cancelled projects, and this may introduce estimate error to our results.

The scale of stranded assets changes along the time horizon when being stranded. In Scenario 1, with no new installation during the 13th FYP period, the newest stranded unit was put into operation in 2014. With a service life of 30 years, the total time series covers 2016–2043. For each year, the series plots the total estimated asset stranding scale if the value of the generating assets declines unexpectedly in that year.

In addition to the estimated asset stranding charges, we overlay 3-year windows to remove coal-fired generation from the energy system: 5 years, 10 years, and 15 years. We select these three windows as they are compatible with the impact of risk factors chosen previously, such as regional factors, including atmospheric pollution, CCS and BWS; and generation unit factors, including operation year, heat rate, and pollutant emissions' performance. In all three windows the start date is 2016, and the known excess scale is 9186 MW in Scenario 1. In the baseline situation—the most extreme case, where coal power is decommissioned now—the total impairment charges would be RMB63.3 billion in 2016. In the 5-year window (2020), total asset stranding charges are RMB46.2 billion. The standing charges in the 10-year window (2025) are RMB29.1 billion. Finally, the 15-year scenario estimates total asset stranding charges to be RMB 14.9 billion. The linear decrease in stranded charges of existing capacity along the time horizon is due to the partial recovery of stranded assets through operation and depreciation.

Figure 18 the value of stranded assets in Jilin under Scenario 2



In scenario 2, half of the new coal projects (under construction and planning), or 3500 MW would be built by 2019. A small fraction (700 MW) of these would be commissioned by 2018, while most would be commissioned by 2019. Hence, in this scenario, the total time series covers 2016–2048. Starting with 9643 MW stranded capacity at 2018, in the baseline situation—the most extreme case, where coal power is decommissioned now —the total impairment charges would be RMB86.3 billion in 2019, RMB34.1 billion more than in Scenario 1 at the same year, largely because newly installed capacity led to 3500 MW more stranded assets in the existing capacity. In the 5-year window (2020), total asset stranding charges are RMB78.1 billion. The stranding charges in the 10-year window (2025) are RMB51.6 billion. Finally, the 15-year scenario estimates total asset stranding charges to be RMB 28.6 billion. The extensive commission of new capacity in 2019 is the main factor contributing to the increase of stranded charges.

In Scenario 3, all the new projects under construction and planning would be commissioned by 2019, and there would be no new approval after 2019. The assumption is that a total of 7070 MW new capacity would be commissioned by 2019, while 700 MW be commissioned by 2018. In the most extreme situation, where all the excess capacity was to be decommissioned in 2019, including some of the plants newly put into operation, the stranding charges are as high as RMB 110.1 billion. The stranding charges at 5-year, 10-year and 15-year window are RMB99.2, 66.1, and 37.5 billion, respectively.

Figure 19 The scale of stranded coal assets in Jilin under Scenario 3

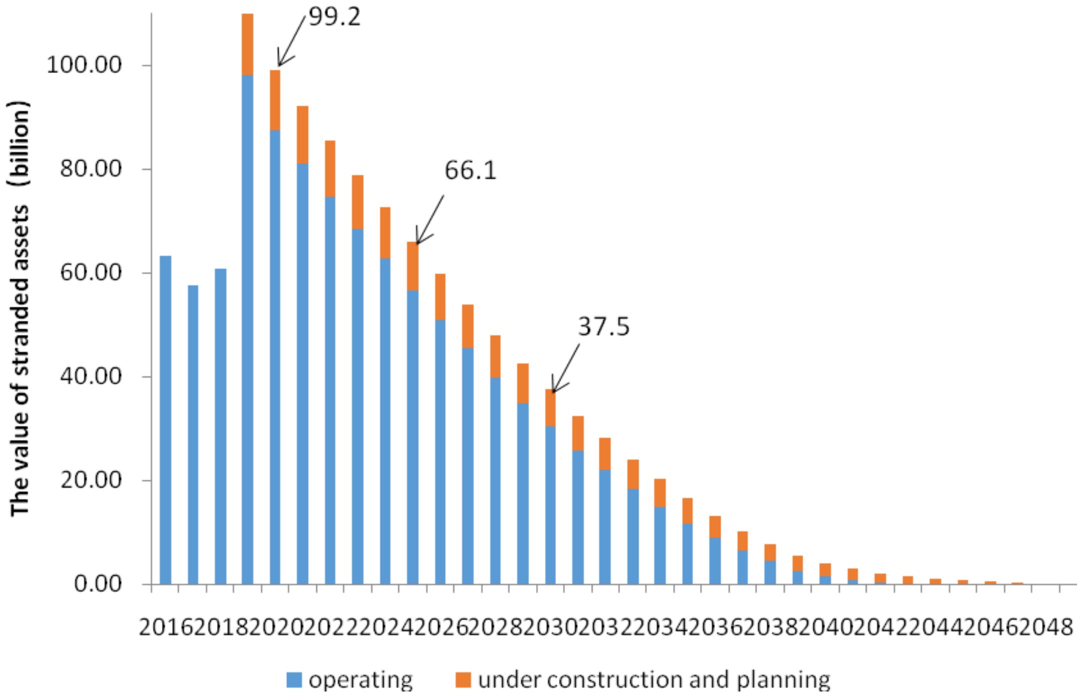


Table 8 Estimate of stranding asset charges in Jilin under different scenarios

Scenario	Stranding year	Existing capacity	New capacity	Total (RMB billion)
	2020	46.2	0	46.2
1	2025	29.1	0	29.1
	2030	14.9	0	14.9
	2020	73.8	4.3	78.1
2	2025	48.1	3.5	56.1
	2030	25.9	2.7	28.6
	2020	87.5	11.7	99.2
3	2025	56.6	9.5	66.1
	2030	30.4	7.1	37.5

A comparison of three scenarios clearly reveals that strict control on new installation can effectively avoid the consequence of larger scale of stranding assets and the corresponding loss. For a province such as Jilin, which has serious oversupply and weak demand growth accompanied by great uncertainty and huge renewable substitution potential, earlier halting of new coal power projects reduces the risks of avoidable stranding assets correspondingly.

With the change of scenarios, the power generation groups will be faced with increasing stranded scale (Figure 3-11). In scenario 1, the Datang Group has the most stranded coal power capacity, while the Guodian Group and the State Power Investment Group are behind.

The stranded scale of the Huaneng Group increases rapidly in Scenario 2, as does that of the SPIC Group.

Figure 20 The stranded assets of major power generation groups in Jilin Province under different scenarios

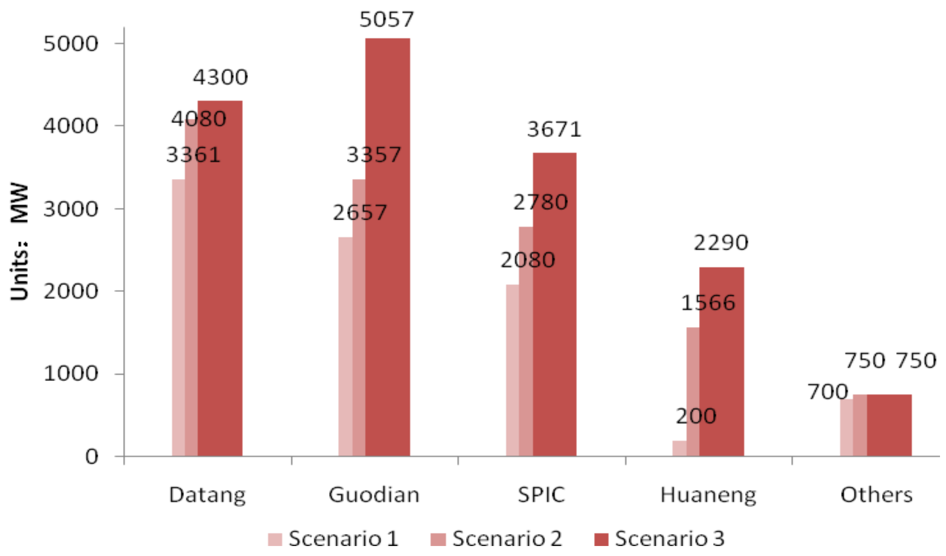
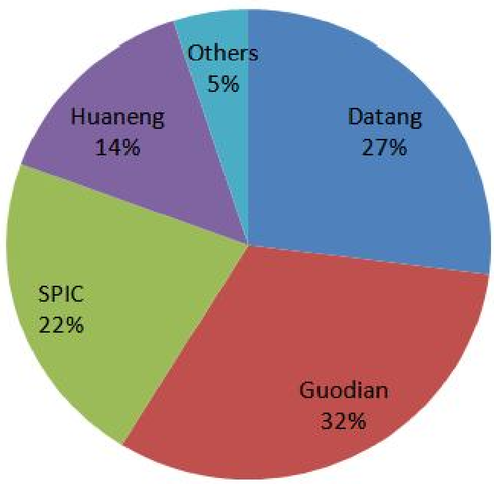


Figure 21 Proportion of stranded coal power in generation group in Jilin under scenario 3



In Scenario 3, if all the new projects were commissioned, the stranded capacity of the Guodian Group would reach 5057 MW, accounting for 31% of total stranded capacity. Considering that Guodian accounts for only 25% of total coal capacity in Jilin, its share of total stranded capacity implies that its stranded risks are disproportionally higher than are those of other groups. Meanwhile, the Datang Group, the State Power Investment Group, and the Huaneng Group account for 27%, 23%, and 14% of estimated stranded capacity, respectively.

In Scenario 3, with the exception of two 600 MW units of the Huaneng Group, all the stranded units are sized below 600 MW. In the top four generators, all units below 200 MW will be stranded if coal power is to be offline. Guodian has the highest stranded share because its units are older and smaller on average than are those of other groups.

Figure 22 Proportion of different stranded assets capacity level

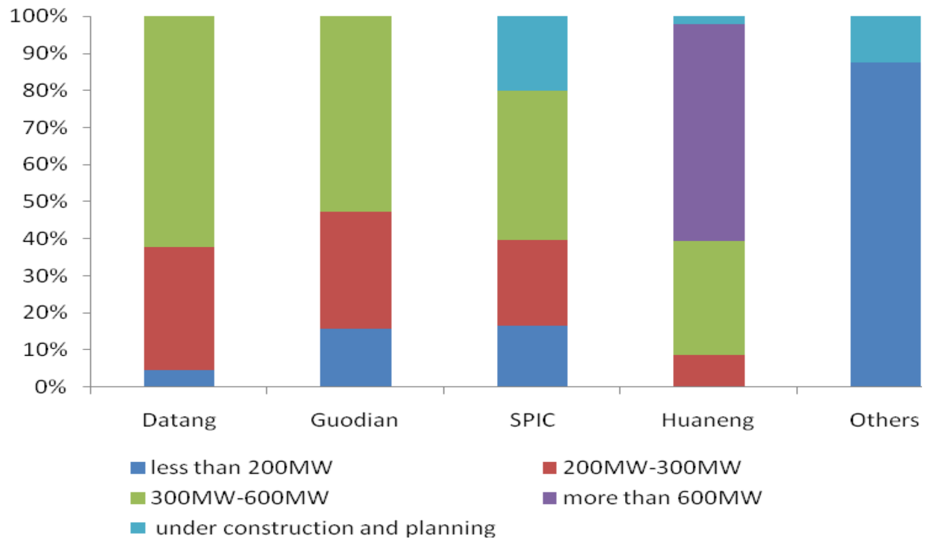
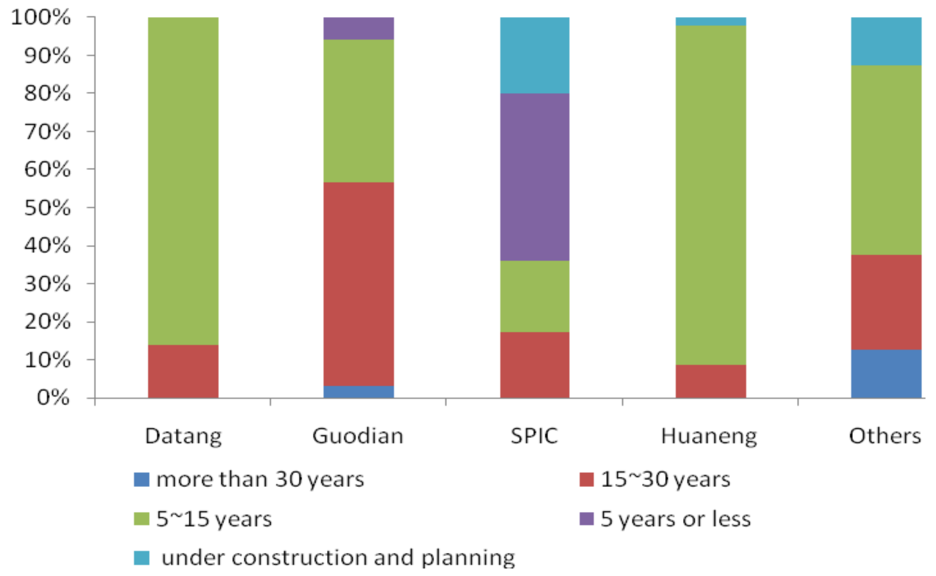


Figure 23 Operation Life of stranded coal power owned by major generating Groups in Jilin under scenario 3



Besides the companies that own coal power assets, other stakeholders, such as employees, financial institutions, and even local government, could be negatively affected by the stranded assets.

Employees in the coal power plant: In the short term, the existence of stranded assets means that companies will not be able to obtain revenue through power generation to pay employees. However, in the long run, severe stranded assets will lead to coal power plants shutting down and staff unemployment. The limited skill of coal power employees makes it difficult for them to find a new job in other industries, which means that their resettlement will be harder.

Financial institutions: As the huge investment in the construction of coal power plants mainly comes from loans from banks and other financial institutions, the existence of stranded assets increases significantly the default risk of loan repayment. New coal power projects, which are especially influenced by short operational life and decline of utilisation hours, cannot obtain enough revenue to repay the loan during the repayment period, which damages the interests of financial institutions badly.

Local government: Firstly, the government will suffer a large amount of unpaid tax revenue because of stranded assets. Moreover, staff resettlement also needs financial resource input from the government, since the coal power companies are mostly state-owned enterprises. Finally, the emerging stranded coal assets may also make the government suspend or abort the planning/approval of new coal power projects, which will increase the cost of government operation.

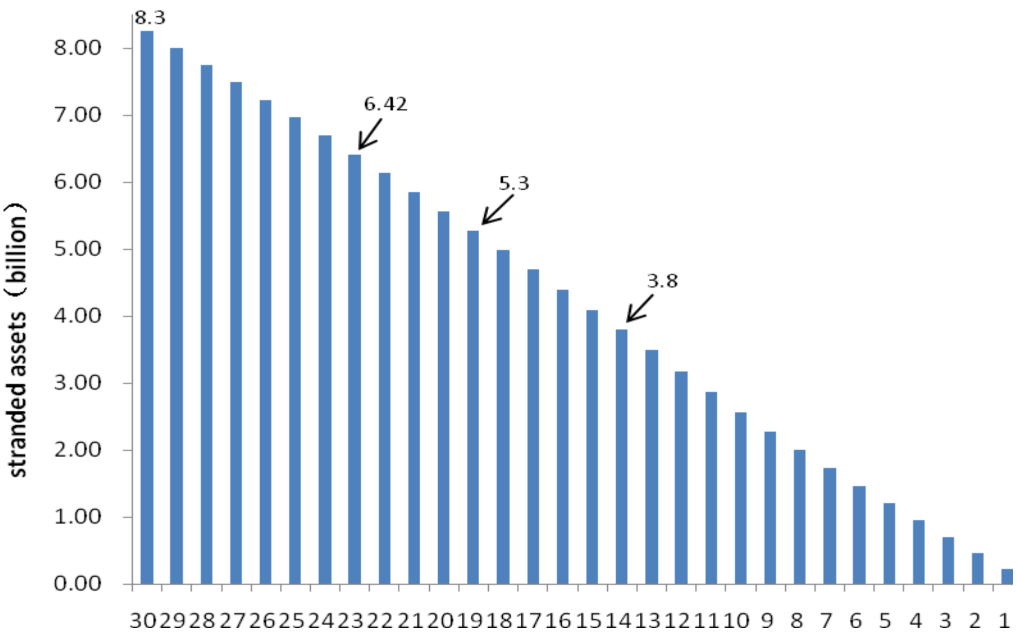
Here for the purpose of illustration, we will choose a representative coal-fired unit to analyse the possible influences of stranded assets on the stakeholders.

Huaneng Jiutai Power Plant Phase I has two 670 MW supercritical units, which are the largest in unit size and have the best performance in Jilin province to date. The total dynamic investment of first phase project reached 5.346 billion RMB. It was approved by the National Development and Reform Commission on 26th February, 2007, construction was officially started on 13th May 2007, and two units were put into commercial operation on 24th October and 6th December, 2009, respectively. When estimating the value of stranded assets, the main parameters are as follows. The unit cost of investment is 3930 RMB/KW, annual utilisation hours are 3841 h, the coal consumption rate of power generation is 282 gce/kWh, the coal consumption rate of power supply is 289 gce/kWh, the coal price is 483 RMB/tonne, the auxiliary power consumption rate is 5.57%, and the number of employees is 290 for two units.

If such a unit was stranded when commissioned, the stranded value would be 8.262 billion RMB. The stranded value would reach 6.418 billion RMB if the stranding year was 2016, while the amount would be 5.282 billion RMB if the stranding year was 2020.

If 2016 was the stranding year, the power plant would be stranded for 23 years ahead of its designed service life, which means that the stranded wage income of 145 employees per unit would be 1.3 billion, stranded loans to banks would reach 540 million RMB in the remaining 8 years of the repayment period (15 years for the total repayment period), and the government would lose 1.3 billion RMB of tax revenue. As can be seen, stranded coal power assets will lead to enormous losses for the various stakeholders.

Figure 24 The stranded value of a single 670MW unit of Huaneng Jiutai Power Plant



Impact on the power system and renewable energy

To understand the impact of excess coal power on the power system and renewable energy, one must know the basic institutional mechanisms underlying China's power system operation.

Due to persistent power shortage, supply capability has always been the top concern of power system planning and construction in China. Internationally, electricity system planning takes different forms in different industry structures and local contexts. Across these different structures and contexts there are two commonly found planning processes: (1) generation adequacy planning, which attempts to ensure that generation capacity will be adequate to reliably meet expected demand at least cost; and (2) transmission reliability planning, which attempts to ensure that the transmission system will be able to reliably deliver power to consumers.

Electricity planning in China differs significantly from this international paradigm. The primary vehicle for planning in China's electricity sector is the 5-year planning process, a comprehensive, hierarchical, nation-wide effort that enumerates policy directions and key investment projects across the entire economy. Generation and transmission investments in the 5-year planning process are not based on reliability or cost metrics. Instead, over the last 15 years, with demand growth exceeding 10% per year, electricity planning has become subservient to breakneck capacity expansion.[33]

Though a new round of power sector reform has been initiated since 2015, a planned and regulated system is still the main feature of China's power system. First of all, wholesale generation price is not formed based on market competition, but by government regulation. It should be noted that the on-grid benchmark tariff for coal power, regulated by NDRC, is set at a level that should provide a reasonable return to investors under current or expected investment and operation conditions.

Secondly, the output of generators is subject to an annual generation plan. Provincial planning agencies, typically provincial Economy and Information Commissions, are responsible for planning annual generator output. For provinces that do not use energy efficient dispatch, each year provincial agencies develop an annual generator output plan that is proposed by the provincial grid company, based upon the principle of grandfathering. Annual and monthly output totals from this plan are included in annual contracts for generators. Annual output plans are intended to guarantee operating hours for generators, subject to system constraints, and are not intended to be "guiding" targets. The grid dispatcher will then disaggregate the annual and monthly output plan into daily output curves, which, in most provinces, are only allowed to deviate from the annual plan in response to changes in hydropower output and load conditions. In other words, the actual implementation of the output plan by the dispatcher is to allocate roughly the same capacity factors for the same kind of generators to allow an equivalent chance for generators to recover

[33] Kahrl, F., and Wang, X., "Integrating Renewables into Power Systems in China: A Technical Primer — Power System Operations", Beijing, China: Regulatory Assistance Project, 2014. Available at: http://www.raponline.org/document/download/id/7459.

investment and gain return. Hence, the equivalent utilisation hours' dispatch is employed currently in China.

In 2007, the NDRC, the State Electricity Regulatory Commission (SERC), and the Ministry of Environmental Protection (MEP) announced a pilot "energy efficient" dispatch system in Guangdong, Guizhou, Henan, Jiangsu, and Sichuan Provinces.[34] This system specifies a dispatch order, with renewable, large hydropower, nuclear, and cogeneration units given priority over conventional thermal units, and conventional thermal units within each category (e.g., coal-fired units) being dispatched according to efficiency (heat rates) and emissions' rate.

In 2010, energy efficient dispatch was extended to the five provinces in the Southern Grid. However, although the original pilots are ongoing, energy efficient dispatch has not been expanded to the national level. The most difficult challenge to implementing energy efficient dispatch has been the generation pricing system, which has not changed to accommodate changes in dispatch. As a result, equivalent utilisation hours is still the method of dispatch in China.

SERC established the first, and still current, formal definition of ancillary services in China in its 2006 "Temporary Measures for Ancillary Services Management for Interconnected Generators".[35] These definitions, which were intended to provide a basis for fairly compensating generators, classified ancillary services into "basic" (uncompensated) and "compensated" services. All generating units are obligated to provide basic ancillary services; basic load following requirements, for instance, are allocated to generators, either as part of the generator output planning process or implicitly through dispatch order tables. SERC's "Management Rules for Generator Interconnection and Operation" stipulate that grid companies should allocate ancillary services' requirements to generators so that, adjusted over the course of a year, equivalent kinds of generation technologies in the same grid have the same ancillary services' requirements.

Under current law, grid companies are required to give renewable energy priority in dispatch and, by extension, in output planning. Priority dispatch in China takes two forms. First, SERC's 2007 "Regulatory Measures for Grid Companies' Full Purchase of Renewable Energy" requires grid companies to purchase all renewable energy, regardless of dispatch system,

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[34]NDRC, State Environmental Protection Administration (SEPA), SERC and National Energy Working Group, "Pilot measures for implementing energy efficient dispatch", <节能发电调度办法实施细则（试行）>, 2007, No. 523.

[35]SERC, "Management rules for ancillary services for interconnected generators", <并网发电厂辅助服务管理暂行办法>, 2006, No. 43.

subject to grid security constraints.[36] Second, in provinces that use energy efficient dispatch, non-fossil fuel resources are prioritised in dispatch order, similar to priority dispatch policies found in Europe. Purchase requirements have not been successful, as the high level of wind power curtailment indicates. The effect of priority dispatch under the energy efficient dispatch system is not yet clear, as it has largely been implemented in provinces that do not have high penetrations of either wind or solar energy. As an alternative, the NEA has proposed a national system of provincial quotas for renewable energy, to be imposed on provincial grid companies.

Growing penetration of wind power in some provinces has increased the need for deep ramps by coal-fired generators through: (1) reducing minimum net load (load minus non-dispatchable generation) because a higher share of wind output occurs at night, further reducing the need for coal generation at night; and (2) increasing, or at least not reducing, spinning reserve requirements. As a result, the amount of coal generation online remains constant or even increases, while the valley in the peak–valley difference decreases, further reducing load factors. High penetrations of solar energy will lead to a similar problem, to the extent that they reduce afternoon net load to much lower levels.

To sum up, generator output planning, and its link to investment cost recovery for thermal generators, creates a conflict between renewable and thermal generators. For wind and solar energy, output is inherently variable and growth in output may exceed growth in demand, reducing output for other generators. As long as fixed cost recovery for thermal generators, and the idea of 'fairness' in adjusting their annual contracts, is tied to output, this conflict is not easily reconcilable.

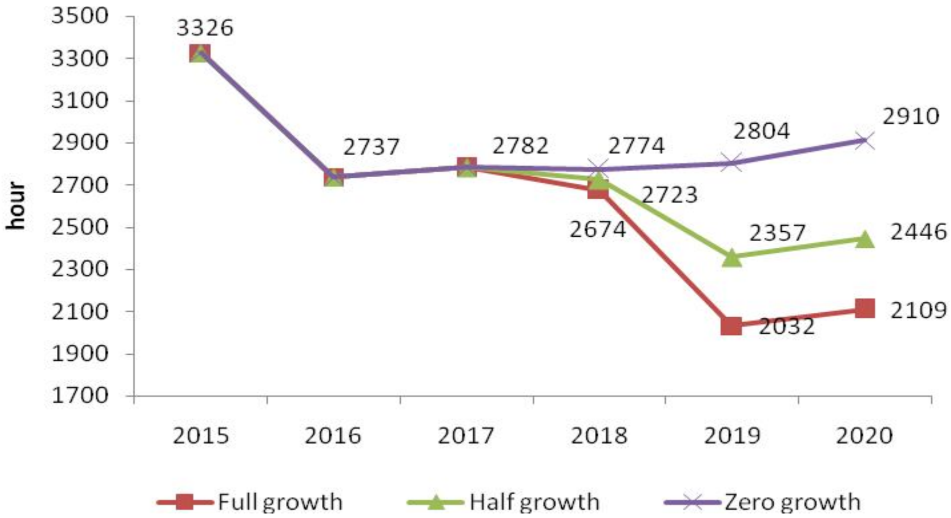
Hence, under existing institutional arrangements, even with serious excess capacity, the low efficiency capacity will not exit the market. Rather, all the generation units, advanced or backward, will operate at low load factor, and the operational efficiency of the power system will be reduced.

With low demand growth, the problem with excess coal capacity will continue. The expected utilisation hours of coal power in Jilin province will continue to decline, even if the growth of wind power is slow. And the half growth or even full coal power growth scenario without proper de-capacity policy will lead to further deterioration in the utilisation of coal power. We expect a deep drop in the utilisation hours of coal power in 2019 under half-and full-coal power growth scenarios, and then the utilisation hours will stabilise at a low level. Even

[36] SERC, "Regulatory measures for the full purchase of renewable energy", <电网企业全额收购可再生能源电量监管办法>, 2007, No. 25.

under zero coal power growth, the utilisation hours cannot return to 3000 h in 2020 (Figure 3-16). (see appendix Ⅵ for the methodology).

Figure 25 The estimation of coal power utilisation hours of Jilin province under different scenarios during 13th FYP



For renewable energy, curtailment will become even more serious,[31] because in some situations either the output of coal units under minimum capacity is enough to meet up with system load, or the operational inflexibility of coal power reduces the ramping capability of the system. In the Northeast power grid, where CHP units account for most of the coal power fleet, the issue of minimum coal output constraint is most salient.[37] During 2006–2015, under the call for enhancing energy efficiency by developing CHP units, most of the newly commissioned coal capacity was CHP units. Meanwhile, because many generators want to secure annual generation hours through CHP units, many pure condensing units were retrofitted into CHP units. By the end of 2015, CHP units accounted for 63% of the thermal power in the Northeast power grid and exceeded the demand for central heating. It is estimated that during 2006–2015, the growth of CHP capacity was 2.3 times that of the growth of heating supply. To be specific, in Jilin province, the theoretical heating supply capability was, at the least, larger than the heating demand for more than 25% of the province.[38]Due to the excessive growth of CHP units, the renewable integration capability of the power system under valley load during the heating season has been gradually decreased, which has already jeopardised system security (Figure 3-17). Therefore, in the Jilin power

[37]Kahrl, F., and Wang, X., "Integrating Renewables Into Power Systems in China: A Technical Primer — Electricity Planning", Beijing, China: Regulatory Assistance Project, 2015.

[38]Pei Zheyi, WANG Caixia, HE Qing, et al, " Analysis and suggestions on renewable energy integration problems in China ", [J]. Electric Power, 49(11): 1-7, 2016.

grid peak shaving is extremely difficult during the winter heating season. Even if all the CHP units operate at the minimum output, wind power must participate substantially in peak shaving during the low load period at night. In the Spring Festival and other extreme low load periods, when all the wind and pure condensing units must be fully stopped, there is more than 3000 M power to be balanced.

Due to the problems described above, wind power curtailment in Jilin has been very serious in recent years, especially in winter heating season. The wind power curtailment rate in the first three quarters of 2016 reached 34% in Jilin and is expected to rise to 40%bythe end of year. In response to the serious curtailment situation, the Energy Bureau of Jilin Province formulated the "local absorption pilot program of renewable energy resources", attempting to improve the local absorptive capacity of renewable energy by direct trading of electricity, renewable energy distribution network, electricity substitution pilot, electric heating pilot, and other measures. In addition, the Zarud-Qingzhou Shandong ±800 KV DC transmission line under construction will solve the oversupply and wind power curtailment problems to some extent. However, without significant improvement in curbing excess capacity and power generation structure, the wind power curtailment rate can hardly make a fundamental change. If coal power kept zero-growth during the 13th FYP period, with active local pilot programs, the curtailment rate would be expected to be reduced to about 15% by 2020. However, if coal power projects under planning and construction were put into operation fully, the curtailment rate in 2019 would further rise due to the negative effect of increasing coal power capacity. Even with active local actions, the curtailment rate would remain at a high level of 30% by 2020 in this scenario.

Figure 26 The relation between thermal power and unified dispatch load in Jilin

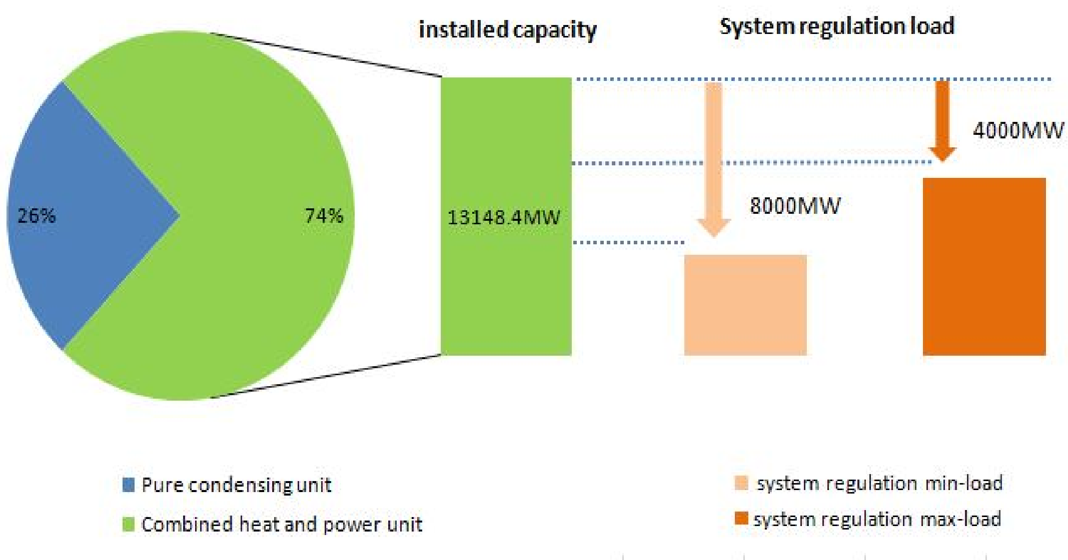
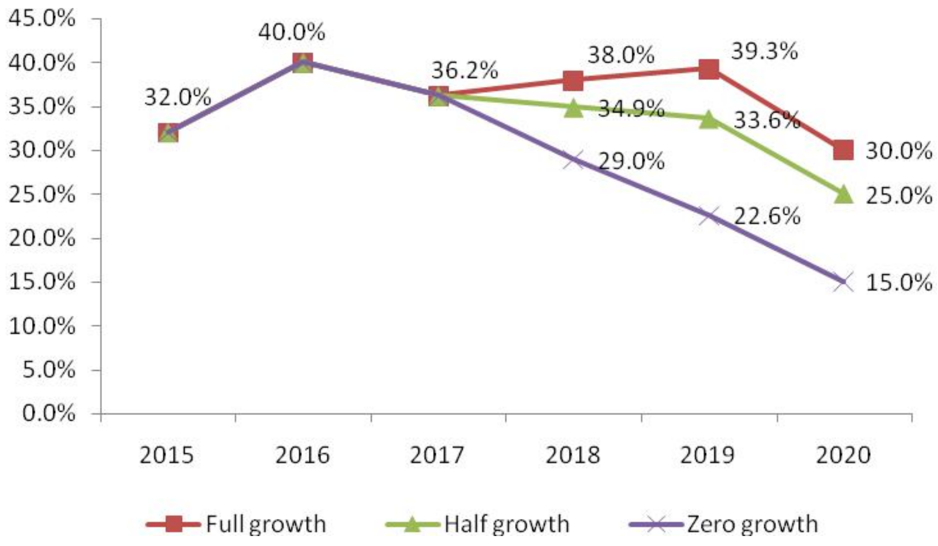


Figure 27 The estimation of wind power curtailment rate of Jilin province under different scenarios during 13th FYP



Note: We employed a method similar to that reported in appendix Ⅴ. However, we made an alternative assumption on coal utilisation hours by considering the local renewable energy absorption policy.

Provinces are required to boost direct power purchase to release the bonus of power sector reform as soon as possible. Direct power purchase will reach 30% of industrial electricity consumption by 2016 and 100% by 2018. Under serious oversupply, direct power purchase will push down the contract price, exacerbate the loss of generators, and enlarge the stranded asset risks. In addition, without the establishment of a spot market, under direct power purchase it will be more difficult to integrate renewable energy into the power system. The lowered coal power price will attract industrial customers to sign a long-term power purchase contract, which, in turn, will render renewable energy even less attractive because of the fixed feed-in tariff and will further squeeze the market space of renewable energy.

4. Policy mechanisms for coping with stranded assets

According to the preceding analysis, it is evident that stranded assets will damage the interests of investors, employees, financial institutions, and local governments. In fact, since 2016 all the top generators in China have already encountered loss of profit. According to the third quarter report of the Datang Group, the cumulative net margin of this company was negative RMB 3 million for the first nine months of 2016, and the expected loss for the first three quarters is estimated at RMB 2.87 billion.[39]In the long run, the expansion of stranded assets will not only lead to serious waste in investment but will also constitute barriers for energy system transition in China. Improper disposition of the stranded assets can even have an impact on social stability issues.

Hence, it should be a top concern for local government and the energy ministry to exert strict control over new coal projects and properly dispose of existing stranded assets. On one hand, green financing policy should be deployed to confine investment in coal power and prevent the birth of new stranding assets. On the other hand, local government can learn from the de-capacity experience in the coal and steel sectors and design an explicit exit pathway for excess coal power as early as possible.

Strengthening green finance

With Green financing,[40] the financial sector will make environmental protection a fundamental policy and take environmental impact into full consideration during routine decision-making on investment and financing. All the returns, risks and costs pertaining to environmental conditions should be integrated into the routine operations of the financial sector to reallocate the economic resources for a sustainable society. With green economy becoming the main driver of global sustainable development, green financing has become the priority in many countries. Since 2007, China has enacted a series of policy documents to encourage financial institutions in developing the green credit business. In February of 2012, the China Banking Regulatory Commission (CBRC) issued its Guide on Green Credit and required commercial banks to strengthen the management of environmental and social risks, which is a clear signal that green credit policy will be integrated into the policy framework of environmental protection and pollutant abatement. According to the Overall Institutional

[39]Polaris power net, "Datang Group released three quarter report: net profit -315 million , decreased 187.69% by last year", 2016

[40]People's Bank of China, "the guidance on building a green financial system", <关于构建绿色金融体系的指导意见>, 2016.

Reform Program on Ecological Civilisation by State Council in September of 2015, a host of green financing mechanisms, including green loans, green bonds, green stock indexes and related investment products, and green development funds, are required to be studied, established, or strengthened. In the Outline for 13th FYP Planning, green financing is regarded as a national strategy in the new development stage. With a nascent development stage in about one decade, a green financing system consisting of green loans, green bonds, green funds, and green stock indexes has taken shape in China (Figure 4-1, Table 9).

Table 9 Reform orientation of Chinese green financial system

No.	**Composition of green financial system**	**Reform orientation**
1	Green credit	Intensify green credit granting; build a policy system to support green credit; set up a green assessment mechanism for bank; promote securitisation of green credit assets; clarify the environmental protection responsibility of lenders.
2	Green bonds	Improve rules and regulations related to green bonds, unify the definition standard of green bonds, and reduce the financing cost of green bonds.
3	Green stocks	Support eligible green enterprises for financing from the stock market and refinancing; set up a green stock index and develop related investment products; set up a mandatory disclosing mechanism for environmental protection information.
4	Green development fund	Set up green development funds to enable market-oriented operation.
5	Green development under PPP mode	Introduce PPP mode in green industry.
6	Green insurance	Set up a compulsory liability insurance system concerning environmental pollution in the high risk environment field.
7	Financing tool for environmental rights and interests	Develop carbon financial products; promote establishment of environmental rights and interests trading markets relating emission right, energy saving and use right and water right; develop financial tools based on environmental rights and interests, such as the rights of carbon emission, emission rights, and energy saving and use rights.
8	Green finance-backed international cooperation	Promote international cooperation of various forms in green financial fields.

Data source: Integrated Reform Plan for Promoting Ecological Progress and Guiding Opinions on Building a Green Financial System.

Specific green financing measures that can be deployed in the power sector to curb new coal power capacity and steer clean power investment include the following:

- Implement compulsory information disclosure on environmental and climate change risks in the listed generation companies, which can provide accurate assets' risk information to investors and institutions. In addition, require the commercial banks to conduct environmental pressure tests when approving loans for fossil energy projects.

- Guide commercial banks to establish their own green credit system under the instruction of Green Credit Guide by the People's Bank of China (PBoC). Identify the differential of credit rating scales between coal power (red alert regions in particular) and clean power projects. Using this approach, support loans on clean energy while discouraging loans on coal power by the commercial banks.

- Accelerate the marketisation of green bonds and green funds. Encourage the financial market to invest in the low carbon sector and cut down the direct financing cost of green companies with public-private partnership (PPP), direct government funding, and easier admission procedures, etc. (Table 10);

- Reinforce support for issuing green stock shares. Support eligible green companies to seek financing and refinancing by listing them on the stock market. Establish a green stock index and related investment products.

Table 10 Energy related projects backed by green bonds

Project	Scope of application	Policy document
Focus of support	(1) Technological transformation projects for energy-saving and emission reduction, including ultra-low emission and energy-saving transformation, waste heat and pressure utilisation, upgrading and rebuilding of energy saving and environmental protection systems in coal-fired boilers, energy efficiency promotion of the motor system, comprehensive improvement of corporate energy efficiency, and green lighting in coal-fired power plants. (2) Green urbanisation projects—including green building development, building industrialisation, energy saving renovation of existing buildings, sponge city construction, smart city construction, smart power grids construction and new energy automobile battery charging facilities. (3) Energy cleaning and efficient utilisation projects—including efficient and clean utilisation of energies like coal and petroleum. (4) New energy development and utilisation projects—including development and utilisation of hydropower, wind energy, nuclear energy, solar energy, biomass energy, terrestrial heat, shallow geothermal resources, ocean energy, and air energy. (5) Energy conservation and environmental protection industry projects—including industrialisation of major energy conservation and environmental protection equipment and technologies, contract energy management, and construction of energy conservation and environmental protection industry base (park). (6) Low-carbon industry projects—including industrialisation of low-carbon technology and related equipment mainly popularised by the state, low-carbon product production projects, and construction projects related to low-carbon service. (7) Low-carbon development pilot demonstration projects—including low-carbon infrastructure and carbon management platform construction projects related to low-carbon energy, low-carbon industry, low-carbon transport and low-carbon building in low-carbon pilot projects of province and city (town), low-carbon pilot projects of city (town), low-carbon pilot projects of community, and low-carbon park project.	Notice of the General Office of NDRC on printing and issuing Guideline for Issuing Green Bonds ([2015] NO. 3504).
Project scopes	(1) Energy conservation (industrial energy saving; sustainable building; energy management centre; urban and rural infrastructure construction with energy-saving efficiency) (2) Clean energy (wind power generation; solar photovoltaic power generation; smart power grids and energy internet; distributed energy resource; solar power heat utilisation; hydroelectric generation; other new energies' utilisation)	Notice on Matters Related with Issuing Green Financial Bonds (Notice by People's Bank of China 〔2015〕 NO. 39)

Referring to the de-capacity policy in coal and steel sectors

The de-capacity policy and related experience in the coal and steel sectors can be used as reference for the phase-out of coal power. The State Council put forward the de-capacity targets in these two sectors in early 2016. For the coal mining sector, the target is to close capacity at about 500 million tonnes and restructure coal mining assets with another 500 million tonnes' production capacity in 3–5 years.[41]In February 2016, the State Council released the "Opinions on Resolving Excess Capacity in the Coal Mining Sector" and provided concrete measures to deploy de-capacity, including financial subsidies and awards, staff resettlement, financial support, land policy, and technology upgrading. As regards fiscal policy, a special fund has been established to provide subsidy and award. As regards financial policy, financing support will be provided to mining enterprises capable of market competition. Support will be given to them to lower capital costs by issuing lower cost bonds to substitute for high cost financing. Support will be given to commercial banks to sell non-performing assets to specialised assets' management companies to enhance assets' disposition efficiency. As regards staff resettlement, by combining the function of enterprises and social security system, eligible employees will be granted early retirement, while other employees will be provided with reemployment training and aids. In 2016, the State Council also released a de-capacity policy for the steel sector.[42]Many ministries, including the Ministry of Finance (MOF), the Ministry of Land and Resources, and local governments, have since put forward concrete measures to facilitate de-capacity in these two sectors. For example, MOF established a special Structural Adjustment Fund for industrial enterprises and arranged RMB 100 billion to provide subsidy and award de-capacity.[43]Hebei is the province with the largest steel capacity in China. The Hebei provincial government issued an Implementation Programme on Staff Resettlement in the Coal and Steel Sectors and put forward ten measures for promoting reemployment of those unemployed workers in the de-capacity process.[44]

The above-mentioned policies play a critical role in de-capacity in the coal and steel sectors. However, the situation in the power sector is much more complicated: during the 13th FYP period and over the longer term, coal will continue to be the principal source of power supply in China. In the short and medium term, coal power will also play a critical role in helping to integrate renewable energy. Therefore, the problem of excess coal power capacity is not a simple thing, and its solution needs systematic thinking, including the complicated interaction of energy system optimisation, institutional reform, and power market reform. Market reform is certainly the right direction, but simply leaving it to market forces cannot

[41]The State Council, " Opinions on Resolving Excess Capacity in the Coal Mining Sector", <关于煤炭行业化解过剩产能实现脱困发展的意见>, 2016

[42]The State Council, " Opinions on Resolving Excess Capacity in the steel Sector", <关于钢铁行业化解过剩产能实现脱困发展的意见>, 2016.

[43]Ministry of Finance , "Special Structural Adjustment Fund for industrial enterprises", <工业企业结构调整专项奖补资金管理办法>, 2016.

[44]Hebei provincial government, "Implementation Program on Staff Resettlement in the Coal and Steel Sectors", <关于做好化解钢铁煤炭等行业过剩产能职工安置工作的实施意见>, 2016.

solve all the issues. Under China's unique national conditions and the power sector's institutional environment, administrative and regulative measures must work with the market to ensure the desired effects. In particular, before the full operation of a true power market, powerful administrative policy can be the most effective in the short run.

Deepening power sector reform

Based on the preceding analysis, the following measures can be taken for solving coal overcapacity issues and smoothing the frictional exit process of stranded assets from the market.

- Exert hard control over new projects. Stop all the new coal power projects under construction and planning. According to construction progress, suspend these projects that can be terminated while postponing those that cannot be terminated. Cancel all planned projects. Maintaining strictest control over new projects, strive to ensure that coal power will not compete with renewable energy in the new demand scenario.

- Compress present coal capacity. Implement decommission policy strictly. Decommission all these units that have already served for 30 years and longer, in addition to those units that have served more than 25 years but cannot meet the new energy efficiency and emission performance standards with retrofitting. With this policy, it is expected that at least 3000 MW of ageing coal capacity can be retired during the 13^{th} FYP period.

- Conduct flexibility retrofitting in existing units. According to the requirements of wind development and grid integration, conduct flexibility retrofitting in 3000 MW of the existing coal fleet (including CHP units). Meanwhile, retrofit 1000 MW extract condensing CHP units into pressure CHP units. In total, retrofitting can provide at least 2000 MW of fast ramping flexibility, while effectively cutting the system minimum output during the heating season.

- Curtail annual output plans. According to the requirements for deregulation of annual production plans, all newly commissioned coal units will not be given any output plans. Meanwhile, gradually curtail the share of annual plans for existing units.

- Develop the power market actively. The ancillary service market in the Northeast power grid was initiated in 2016. With the ancillary service market to properly compensate the provision of ancillary and flexibility services by coal units, some coal units will be gradually transformed from serving base load to providing flexibility service in the power market. The benefits are twofold. On the one hand, new sources of market revenue can be provided to partly offset the loss due to excess capacity and smooth the exit process. On the other hand, the vital flexibility service can facilitate the large-scale integration of renewable energy into the power system. Meanwhile, promote the development of a spot market with firm advance of transmission &distribution pricing reform. The target is to establish an integrated power market system consisting of a forward market and a spot market made up of day-ahead, intra-day and ancillary service markets.

5. Conclusion and policy implications

Conclusion

Under the circumstance of slow demand growth and oversupply, the utilisation rate of coal power in Jilin has been deteriorating continuously, and the risk of large-scale stranded assets has appeared. During the 13th FYP period, with stricter environmental constraints and accelerated power market reform, coal power in Jilin will be faced with larger stranding risks because of long service life, low efficiency, and poor pollutant emission performance.

This report quantifies the scale of stranded assets, according to the uncertainties in coal capacity increase, under the assumption of 3.5% annual demand growth and 7% wind capacity growth in Jilin during the 13th FYP period. If there was no coal capacity growth, then the excess capacity of coal power would range around 9000–9360 MW during 2016–2020. In this situation, in the most extreme case, where coal power is decommissioned immediately, the total impairment charges would amount to RMB62.3 billion in 2016. Even postponing the stranded time by 5 to 15 years could reduce the stranded charges to a range of RMB 14.5–28 billion; the risk is very high and deserves a quick response. However, if all the new projects under construction and planning were put into operation during the 13th FYP period, then the peak of excess capacity would exceed 16,400 MW, while the peak of stranded charges would exceed RMB110 billion, leading to a titanic stranding risk. Even cutting down the new installation by a half, the peak of excess capacity would amount to 13,000 MW and the peak of stranded charges would reach RMB86.2 billion. The conclusion is clear: strict control over new coal installation is the most important and effective measure to curb stranding asset risk.

The top four national generators, Guodian, Huanenng, State Power Investment, and Datang, account for most of the stranded coal power assets in Jilin. In particular, the Guodian Group has the highest stranded asset risks, because more than 50% of its units are small units that have served for more than 15 years. Taking 2020 as the stranding year, the assets impairment would amount to RMB 23.1 billion, 20.1 billion, 25.7 billion, and 22.1 billion in Guodian, Huanenng, State Power Investment, and the Datang Group, respectively. State Power Investment will incur the highest stranded impairment because it has the largest new coal projects. The conclusion here is also straightforward: to avoid heavy loss caused by stranded coal assets, generators must act quickly to adjust their investment and optimise the generation mix.

In addition to the interest impairment to investors and companies, stranded assets will also lead to direct and indirect negative impacts on other stakeholders, including employees, financial institutions, and even local governments. With a typical (2*670 MW) power plant commissioned at 2009 as an example, its stranding at 2016 would incur stranded charges as high as RMB6418 million and lead to employee losses in salaries and benefits of RMB1300 million, commercial bank losses in interest of RMB540 million, and local government tax losses of RMB1300 million.

Policy implications

The top priority is strict control over the new installation of coal power capacity. To avoid more serious issues of stranded assets, we recommend implementation of zero growth policy in Jilin province, in addition to proper disposal of the existing stranded assets. For the identified 9000 MW excess coal capacity, our suggestion to competent provincial energy authority is to shut down and retire 3000 MW ageing coal capacity, conduct flexibility retrofitting in the 3000 MW existing coal fleet (including CHP units)according to the grid integration requirement of wind development, and retrofit 1000MW extract condensing CHP units into back-pressure CHP units. With these measures, the excess capacity in the existing coal fleet can be gradually reduced and, thus, the abrupt decrease in annual utilisation hours can be avoided to prevent further deterioration of coal power's economic performance.

We recommend strengthening coordination among different government agencies to facilitate the smooth and steady phase-out of coal power. A properly designed power market can play a vital role in this process. First of all, we recommend that Jilin provincial government and NEA continue to employ the fiscal subsidy policy that has been employed since 11th FYP period in the shut-down of small coal power. A special fund can be raised from the Structural Adjustment Fund in the electric power sector to subsidise the closed coal power plants and employee reallocation. The coal power companies should work together with local governments to provide reemployment training to unemployed workers and to facilitate their reemployment in the renewable energy industry. Secondly, we recommend that the market operation of auxiliary services in the power market be speeded up and the pricing mechanism improved to mobilise the incentive for coal power in the provision of auxiliary services.[45]In this way, the transition of coal power from base load unit to peak load unit, in particular mothballed and flexibility retrofitted units, can be launched and facilitated. A market mechanism for renewable energy integration should be established, to duly handle

[45]National Energy Administration, "Reply to agreement on carrying out the special auxiliary service pilot of northeast regional electricity market", <关于同意开展东北区域电力辅助服务市场专项改革试点的复函>, 2016.

the retrofitting of coal power, provision of flexibility services, and renewable integration. A market mechanism to compensate ancillary service provided by coal power can help in the friction-smoothing management and partial recovery of stranded assets.

Green financing can work together with power sector planning policy to limit the new capacity. We suggest that the Jilin provincial government strictly follows the policy requirements by NEA and NDRC[46]to suspend the construction of new coal projects while deregulating power generation planning and gradually cancelling the planned portion of power generation. Meanwhile, the provincial government should encourage the newly commissioned coal power plants to be confirmed as peaking units serving the purpose of renewable energy integration.[47] Following the plan of retail competition, direct trading between large industrial customers and generators should be facilitated to display market price signals for distracting coal power investment.[48]As regards financial policy, provincial government can also work closely with the central bank to explore innovative green financing measures. Green funds backed by local government could be established to provide support to green investment and attract investment in renewable and clean power. Green and sustainable market indexes could be developed to promote investors taking environmental concerns into their investment decisions. A green guarantee mechanism, whereby local government takes an active role, can be established to address the financing challenges of green power projects, which are typically riskier in the current market situation. At the same time, commercial banks should be encouraged to generalise the practice of environmental pressure testing, which would significantly increase the difficulty of heavy polluters and GHG emitters (coal power for example) in securing project loans. Financial discount policy should be implemented in the green financing projects, in such a way as to leverage more capital into green energy investment. A reloan policy can also be employed by the central bank to offset the deficit of insufficient input and service on environment protection.

[46]National Energy Administration, "Notice on further standardizing the order of the construction of electric power projects", <关于进一步规范电力项目开工建设秩序的通知>, 2016.

[47]Energy Bureau of Jilin Province, "Regulation rules of power generation targets in Jilin Province", <吉林省发电目标调控规则>, 2016.

[48]Development and Reform Commission of Jilin province, Energy Bureau of Jilin Province, "Jilin province is to carry out the pilot program for the power sale side", <吉林省开展售电侧改革试点方案>, 2016.

6. Appendix

Appendix Ⅰ: A power capacity expansion model to quantify the excess coal power scale

Generally speaking, a capacity expansion model is a least cost capacity installation model with key constraints of energy and power balances.

1. Energy balance constraint

Taking the medium demand and low wind power scenario in 2020 as an example.

Table 1 Estimate excess coal capacity in 2020 with energy balance

<table>
<tr><th colspan="2" rowspan="2">Power Supply</th><th rowspan="2">Planning capacity in 2020 (MW)</th><th rowspan="2">Utilisation hours in 2020 (Ideal situation)</th><th colspan="2">Electricity demand in 2020 (GWh)</th></tr>
<tr><th colspan="2">Total 77437①</th></tr>
<tr><td colspan="2">Hydropower</td><td>4800</td><td>2900</td><td colspan="2">13921②</td></tr>
<tr><td colspan="2">Pumped storage</td><td>1700</td><td>600</td><td colspan="2">1020③</td></tr>
<tr><td colspan="2">Wind</td><td>6901</td><td>2100</td><td colspan="2">14491④</td></tr>
<tr><td colspan="2">Solar</td><td>726</td><td>1600</td><td colspan="2">1161⑤</td></tr>
<tr><td colspan="2">Biomass</td><td>655</td><td>4500</td><td colspan="2">2945⑥</td></tr>
<tr><td rowspan="3">Coal</td><td>Zero growth</td><td>18627</td><td rowspan="3">4700</td><td rowspan="3">45258</td><td rowspan="3">①－②+③*1/3－④－⑤－⑥</td></tr>
<tr><td>Half growth</td><td>22162</td></tr>
<tr><td>Full growth</td><td>25697</td></tr>
<tr><th colspan="6">Quantification of reasonable and excess coal power scale(MW)</th></tr>
<tr><td colspan="2">Reasonable scale</td><td colspan="4">9629</td></tr>
<tr><td rowspan="3">Excess scale</td><td>Zero growth</td><td colspan="4">8998</td></tr>
<tr><td>Half growth</td><td colspan="4">12533</td></tr>
<tr><td>Full growth</td><td colspan="4">16068</td></tr>
</table>

2. Resource adequacy constraint

First, we make an assumption of the resource adequacy values of different generation technologies to peak loads similar to Kahrl (2016).[49]

[49] Fredrich Kahrl, "Coal-Fired Generation Overcapacity in China- Quantifying the Scale of the Problem: A Discussion Draft", February 2016

Table 2 Resource Adequacy Values for Different Generation Technologies

Generation Technology	Resource Adequacy Value (%)
Hydropower	50%
Pumped hydropower	100%
Coal power	100%
Natural gas central-scale	100%
Wind	10%
Solar	30%
Waste incineration	80%
Biomass	80%

As conventional and pumped hydropower stations located in Jilin are directly dispatched by Northeast Power dispatch centre, rather than Jilin Power dispatch centre, we make two alternative assumptions on the contribution of available hydropower resources to the peak load of Jilin:

S1: Hydropower makes no contribution to the peak load in Jilin.
S2: Hydropower can make half the contribution to the peak load in Jilin with the available resources.

We can then estimate the status quo of resource adequacy with available data for 2014. Here we assume a reserve margin of 20% for the regular reserve and another reserve for renewable energy equivalent to the scale of available renewable resources. We can see that, under alternative assumptions on hydropower, the scale of excess coal power ranges between 7030 MW and 7973 MW in 2014 in Jilin.

Figure 1 Comparison of system load and equivalent available resource in 2014 under S1

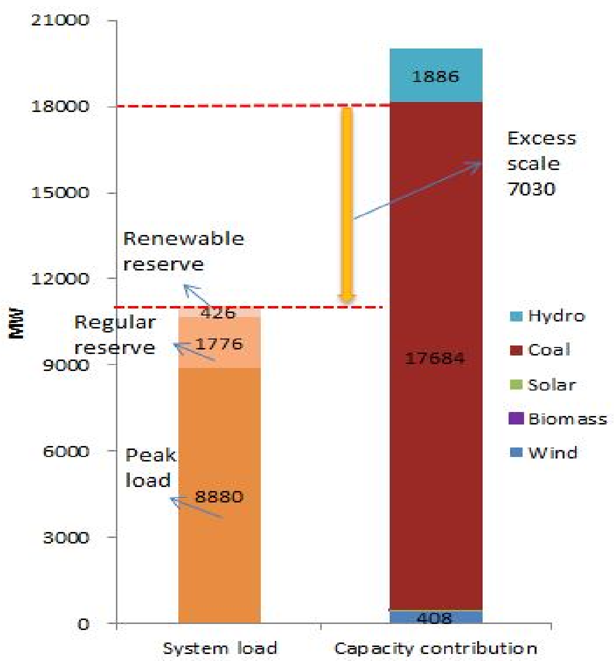
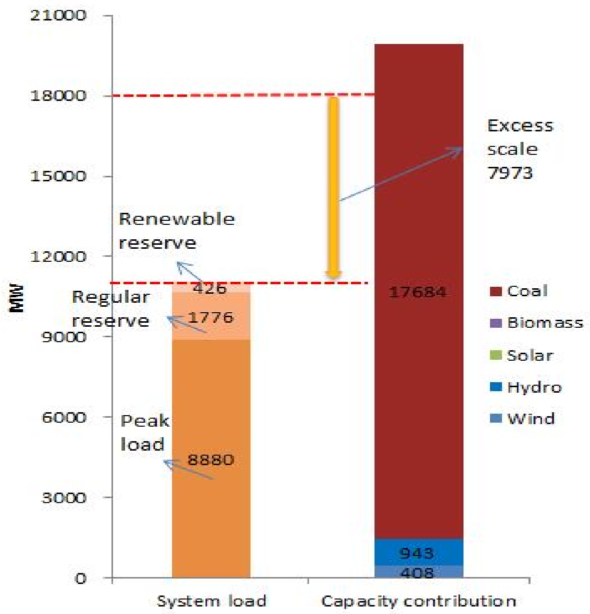


Figure 2 Comparison of system load and equivalent available resource in 2014 under S2



We further estimate the resource adequacy situation in Jilin into 2020. Here we assume that the growth rate of peak load is 1.2 times electricity consumption. Employing the same method and assumption on resource adequacy values of different technologies, we can make the estimate for 2020 under different scenarios of coal power capacity growth.

Figure 3 Comparison of system load and equivalent available capacity under different scenarios in 2020 under S1

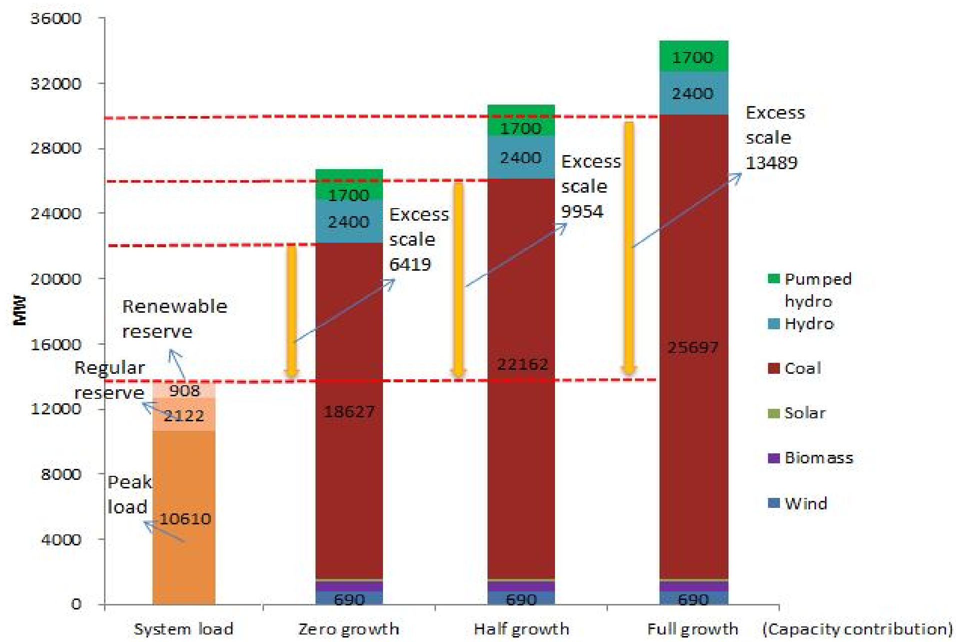
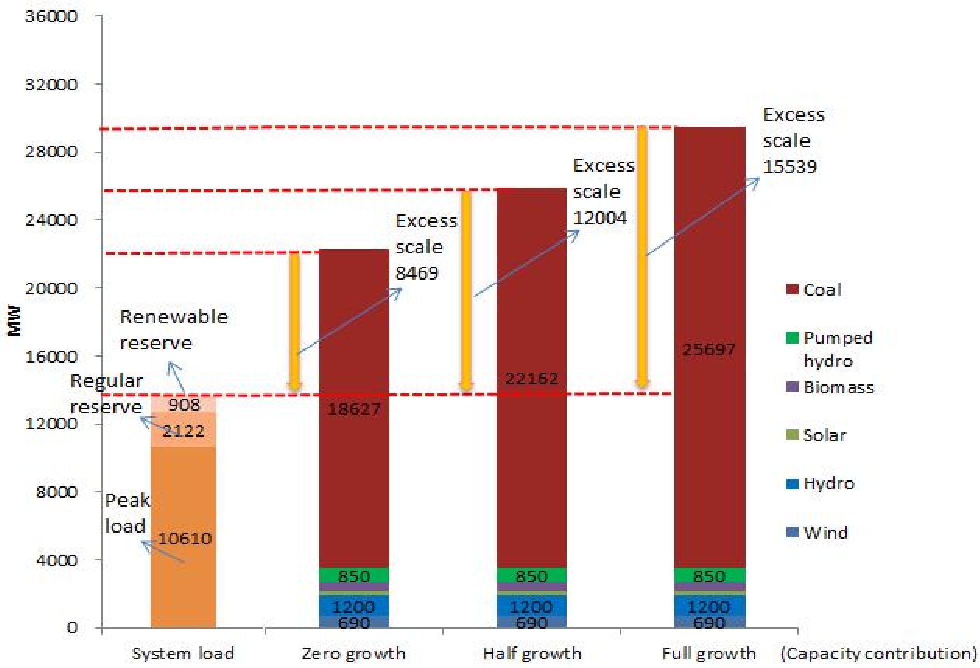


Figure 4 Comparison of system load and equivalent available capacity under different scenarios in 2020 under S2



3. Estimate results

Table 3 summarises the estimates of excess scale of coal power with energy balance and power balance constraints under different coal power capacity growth scenarios. It is evident that the estimated number with power balance is generally smaller than the number with energy balance, but the difference is not very significant, especially when considering the contribution of hydropower to resource adequacy balance. It is also worthwhile pointing out that, under the current mechanism, coal power is not properly compensated for its contribution to the power system in terms of backup and ancillary services, so it is 'stranded', according to our definition, even it is needed for system service. Hence, we will employ the estimate of excess scale with energy balance constraint for further analysis in our report.

Table 3 Excess scale of coal power in Jilin under different scenarios during the 13th FYP

Excess scale(MW)		**2016**	**2017**	**2018**	**2019**	**2020**
Zero growth	Energy balance	9186	9076	9293	9360	8998
	Power balance	8096-9119	7753-8796	7388-8588	6908-8258	6419-8469
Half growth	Energy balance	9186	9076	9643	12895	12533
	Power balance	8096-9119	7753-8796	7738-8938	10443-11793	9954-12004
Full growth	Energy balance	9186	9076	9993	16430	16068
	Power balance	8096-9119	7753-8796	8088-9288	13978-15328	13489-15539

Appendix Ⅱ: Description of cash flow statement of full investment in value estimation of stranded assets

Serial No.	Item	Figure Selection Instructions
1	Cash Inflow	1.1+1.2+1.3
1.1	Product Sales (Operating) Income	From "Income Statement"
1.2	Recovery of Residual Value of Fixed Assets	Calculated on basis of total investment and residual rate
1.3	Recovery of Working Capital	From "Liquidity Fund Estimate Statement"
2	Cash Outflow	2.1+2.2+2.3+……+2.7
2.1	Fixed Assets Investment	From the total investment and desulphurisation and denitration investment in the LCOE model
2.2	Liquid Assets Investment	From "Liquidity Fund Estimate Statement"
2.3	Operating Costs	From the fixed costs and variable costs in LCOE model
2.4	Emission charge	Calculated from the emission load and emission price
2.5	Carbon Emission	Calculated on basis of the carbon market assumptions
2.6	Sales Tax and Surcharges	From the "Statement of Sales Tax and Surcharge"
2.7	Income Tax	From "Income Statement"
3	After-tax Net Cash Flow (1-2)	1-2
4	After-tax Cumulative Net Cash Flow	After-tax net cash flow of this year + after-tax cumulative net cash flow of last year

Appendix Ⅲ: Basis and description for parameters setting

Parameters	Value	Source
Unit Investment Costs (RMB/KW)	Capacity<200 MW 4500 200-300 MW 4300 300-600 MW 4100 600-1000 MW 3400 ≥1000 MW 3202	China Electricity Council, Power Development Report of 2015: Unit Costs Analysis for Coal-fired Plant in 2014
Utilisation hours (hours)	Capacity<200 MW 4810 200-300 MW 4157 300-600 MW 4355 600-1000 MW 4868 ≥1000 MW 5255	China Electricity Council: Statistics of Average Utilisation hours of Power Generation Units of Plantsin China in 2014 (estimating based on this)
Benchmark price (RMB/KWh)	0.37	National development and Reform Commission: Notice on reducing the coal power feed-in tariffs and commercial electricity prices
Lifetime of units (years)	30	Shoucheng Xu, Wei Wang. Existing Problems and Improvement Suggestions on Asset Evaluation of Thermal Power Plant.Thermal Power Generation, 2006.
Own capital funds ratio	30%	The State Council. 《Notice of the State Council on Adjusting the radio of Capital Funds for Investment in Fixed Assets》.The State Council （2009） No.27
Annual interest rate	6%	Obtained through the comprehensive estimate of long-term lending rate of different periods.
Loan term (years)	15	According to the research results of the actual situation in China
Depreciation life (years)	20	The depreciation life (20 years) shall be longer than the loan term (15 years)
Heat rate of power generation (Kgce/MWh)	Capacity<200 MW 334 200-300 MW 331 300-600 MW 313 600-1000 MW 311 ≥1000 MW 289	National Energy Administration: Action Plan for Energy Saving, Emission Reduction, Upgrading and Retrofitting of Coal-fired Power Plants (2014–2020)
Auxiliary power consumption rate	Capacity<200 MW 8.12% 200-300 MW 7.81% 300-600 MW 5.88% 600-1000 MW 5.34% ≥1000 MW 4.28%	According to the research results of the actual situation in China
Water consumption of power generation	2.98	China Electricity Council: Energy Efficiency Benchmarking Data of Thermal Power Generation Units in

(RMB/t)		China in 2014
Sulphur content of coal, SO2 emission factor of coal, CO2 emission factor of coal and NOx emission factor of coal	Sulphur content of coal 1% SO2 emission factor of coal 18% CO2 emission factor of coal 94.5% NOx emission factor of coal 5%	Based on the generation and emission coefficient of industrial pollutants
VAT, enterprise income tax, urban maintenance and construction tax, education surcharges, house property tax, fuel input tax, materials input tax, water input tax and land use tax	VAT17% enterprise income tax 25% urban maintenance and construction tax 5% education surcharges 0.5% house property tax 1.2% fuel input tax 13% materials input tax 17% water input tax 13% land use tax 10 yuan/m^2	Based on the tax laws and relevant regulations promulgated by the State
Rate of overhaul charge, insurance premium, materials costs and other expenses, etc.	Rate of overhaul charge 2% insurance premium 0.25% materials costs and other expenses 0.02yuan/kWh	Set up in accordance with the management quota of the power generation enterprise (e.g. *Standards for Limit of Material Costs and Costs of Overhaul of China Huadian Corporation*)
Employee salary	80000 yuan/year	Research data of typical enterprises and national labour allocation policies
Emission charge (Yuan/ton)	1260	Emission charge rate policies of relevant provinces as reported on the websites of http://huanbao.bjx.com.cn, http://www.gmw.cn, and http://www.sina.com.cn, RMB1.2/pollution equivalent (conversion rate: RMB1.26/kg =RMB1,260/ton)
Fuel costs (RMB/ton)	345	Price Monitoring Center of the National Development and Reform Commission
Direct power purchase percentage	10%	Reporting on Polaris Power Website: A Decade of Direct Power Purchase
Fee for industrial water (RMB/t)	1	Water fee inquiry website of Jilin province

Appendix Ⅳ : Risk scoring grade

Score		**5**	**4**	**3**	**2**	**1**
LRHs	BWS	Extremely high (>80%)	High (40%-80%)	Medium to high (20%-40%)	Low to medium (10%-20%)	Low (<10%)
	CCS	Highly Suitable	Suitable	Possible	Little Possible	Unproven
	Heat Stress	High (2.9)	Slightly High	Medium	Slightly Low	Low (0.2)
	SO_2 (DU)	High (2.0-5.0)	Slightly High (1.25-2.0)	Medium (0.5-1.25)	Slightly Low (0.1-0.5)	Low (0.2) (<0.1)
	NO_2(10^15 molec./cm2)	High (2559)	Slightly High	Medium	Slightly Low	Low (0)
	$PM_{2.5}$ (μ/m3)	Max (290)	Slightly High	Medium	Slightly Low	Low (0)
	Hg (g/km2)	>800	100-800	40-100	2-40	<2
GRHs	Service length (years)	>30	20-30	10-20	5-10	<5
	Unit capacity (mw)	<100	100-200	200-300	300-600	>600
	Coal consumption gap with advanced level(g)	Capacity below 300 mw	>40	25-39	10-24	1-9
	SO_2 gap with near zero emission level (mg/Nm3)	>55	35-55	15-35	0-15	≤0
	NO_2 gap with near zero emission level (mg/Nm3)	>200	50-200	20-50	0-20	≤0
	$PM_{2.5}$ gap with near zero emission level (mg/Nm3)	>35	25-35	15-25	0-15	≤0

Appendix Ⅴ: Risk scoring and ranking of coal power units in Jilin

Units Name	Local Factors								Units Factors							Total
	BWS	CCS	Heat stress	Hg	NO_2	PM2.5	SO_2	Sub total	Operating life	consumption for	Units capacity	SO_2	NO_2	dust	Sub total	
Longtan7#	4	5	5	4	5	4	5	32	5	5	5	5	5	4	29	94
Longtan8#	4	5	5	4	5	4	5	32	5	5	5	5	5	4	29	94
Longtan9#	4	5	5	4	5	4	5	32	5	5	5	5	5	4	29	94
Jihua owned1#	4	5	5	4	5	4	5	32	5	5	5	5	5	4	29	94
Jihua owned2#	4	5	5	4	5	4	5	32	5	5	5	5	5	4	29	94
Longtan14#	4	5	5	4	5	4	5	32	4	5	4	5	5	4	27	91
Longtan15#	4	5	5	4	5	4	5	32	4	5	4	5	5	4	27	91
Xinli1#	4	3	5	4	5	4	5	30	3	5	5	5	5	4	27	87
Xinli2#	4	3	5	4	5	4	5	30	3	5	5	5	5	4	27	87
Longtan10#	4	3	5	4	5	4	5	30	3	5	5	5	5	4	27	87
Longtan11#	4	3	5	4	5	4	5	30	3	5	5	5	5	4	27	87
Yixi1#	4	3	5	4	5	4	5	30	3	5	5	5	5	4	27	87
Yixi2#	4	3	5	4	5	4	5	30	3	5	5	5	5	4	27	87
Yixi3#	4	3	5	4	5	4	5	30	3	5	5	5	5	4	27	87
Guodian thermal14#	4	5	5	4	5	4	5	32	4	5	4	5	3	3	24	87
Guodian thermal15#	4	5	5	4	5	4	5	32	4	5	4	5	3	3	24	87
Changjiang Siping1#	5	2	3	4	5	4	5	28	4	5	5	5	5	4	28	85
ChangjiangSiping2#	5	2	3	4	5	4	5	28	4	5	5	5	5	4	28	85
ChangjiangSiping3#	5	2	3	4	5	4	5	28	3	5	5	5	5	4	27	84
Changchun2nd 1#	4	1	5	4	5	4	5	28	4	5	4	5	5	4	27	84
Changchun2nd 2#	4	1	5	4	5	4	5	28	4	5	4	5	5	4	27	84
Longhua Changchun1#	4	1	5	4	5	4	5	28	3	5	5	5	5	4	27	84
Longhua Changchun2#	4	1	5	4	5	4	5	28	3	5	5	5	5	4	27	84
Dongguan1#	4	3	5	4	5	4	5	30	3	5	5	5	3	3	24	83
Huinan1#	4	4	5	4	4	3	5	29	1	5	5	5	5	4	25	83
Huinan2#	4	4	5	4	4	3	5	29	1	5	5	5	5	4	25	83
Changchun2nd 3#	4	1	5	4	5	4	5	28	3	5	4	5	5	4	26	83
Changchun2nd 4#	4	1	5	4	5	4	5	28	3	5	4	5	5	4	26	83
Guodian thermal 10#	4	3	5	4	5	4	5	30	3	5	4	5	3	3	23	82
Guodian thermal 11#	4	3	5	4	5	4	5	30	3	5	4	5	3	3	23	82
Songhuajiang1st 1#	4	3	5	4	5	4	5	30	3	5	4	5	3	3	23	82
Songhuajiang1st 2#	4	3	5	4	5	4	5	30	3	5	4	5	3	3	23	82
Changchun2nd5#	4	1	5	4	5	4	5	28	2	5	4	5	5	4	25	81
Hangchun2nd 6#	4	1	5	4	5	4	5	28	2	5	4	5	5	4	25	81
Songhuajiang3rd 4#	4	3	5	4	5	4	5	30	1	5	5	5	3	3	22	81
Songhuajiang3rd 5#	4	3	5	4	5	4	5	30	1	5	5	5	3	3	22	81
Songhuajiang3rd 6#	4	3	5	4	5	4	5	30	1	5	5	5	3	3	22	81
Hunchun1#	3	5	3	4	3	2	5	25	4	5	5	5	5	4	28	80
Hunchun2#	3	5	3	4	3	2	5	25	4	5	5	5	5	4	28	80
Erdaojiang1st1#	1	5	3	4	4	2	5	24	4	5	5	5	5	4	28	78
Jiaohe new1#	4	3	5	2	4	3	3	24	3	5	5	5	5	4	27	77
Jiaohe new2#	4	3	5	2	4	3	3	24	3	5	5	5	5	4	27	77

Guodian Jiaohe1#	4	3	5	2	4	3	3	24	3	5	5	5	5	4	27	77
Guodian Jiaohe2#	4	3	5	2	4	3	3	24	3	5	5	5	5	4	27	77
HuadianFengtai	4	4	5	2	3	4	5	27	1	5	5	5	3	3	22	76
Liaoyuan3#	5	3	5	4	5	3	5	30	2	3	2	3	5	3	18	75
Liaoyuan4#	5	3	5	4	5	3	5	30	2	3	2	3	5	3	18	75
GuodianSonghuajiang4#	4	3	5	4	5	4	5	30	1	3	2	4	4	4	18	75
Erdaojiang1st 2#	1	4	3	4	4	2	5	23	3	5	5	5	5	4	27	75
Longjing2#	3	5	3	2	3	3	3	22	4	5	5	5	5	4	28	75
Longjing1#	3	5	3	2	3	3	3	22	3	5	5	5	5	4	27	74
Erdaojiang2nd1#	1	4	3	4	4	2	5	23	2	5	4	5	5	4	25	73
Erdaojiang2nd 2#	1	4	3	4	4	2	5	23	2	5	4	5	5	4	25	73
Changchun3rd 1#	4	1	5	4	5	4	5	28	2	2	2	4	4	4	18	72
Changchun3rd 2#	4	1	5	4	5	4	5	28	2	2	2	4	4	4	18	72
Hunjiang5#	1	5	3	2	3	2	5	21	4	5	4	5	5	4	27	72
LonghuaYanji 1#	3	5	3	4	3	3	3	24	2	5	4	5	3	3	22	70
LonghuaYanji 2#	3	5	3	4	3	3	3	24	2	5	4	5	3	3	22	70
Hunjiang6#	1	4	3	2	3	2	5	20	3	5	4	5	5	4	26	69
Jiangnan1#	4	3	5	4	5	4	5	30	2	2	2	3	2	2	13	69
Jiangnan2#	4	3	5	4	5	4	5	30	2	2	2	3	2	2	13	69
Songhuajiang 2nd 3#	4	3	5	4	5	4	5	30	1	3	2	3	2	2	13	69
Changchun C2#	4	1	3	2	4	4	1	19	4	5	4	5	5	4	27	69
Hunchun 3#	3	5	3	4	3	2	5	25	3	3	2	3	5	3	19	68
Hunchun4#	3	5	3	4	3	2	5	25	3	3	2	3	5	3	19	68
Hunchun2nd3#	3	5	3	4	3	2	5	25	3	3	2	3	5	3	19	68
Hunchun 2nd4#	3	5	3	4	3	2	5	25	3	3	2	3	5	3	19	68
Longhua Baicheng1#	3	2	5	4	4	3	1	22	2	5	4	5	3	3	22	67
LonghuaBaicheng2#	3	2	5	4	4	3	1	22	2	5	4	5	3	3	22	67
Longhua Changchun3#	4	1	5	4	5	4	5	28	1	3	2	3	2	2	13	65
Siping2nd 1#	5	2	3	4	5	4	5	28	1	3	2	3	2	2	13	65
Siping2nd 2#	5	2	3	4	5	4	5	28	1	3	2	3	2	2	13	65
Jiutai1#	4	1	5	2	5	4	5	26	2	4	1	2	3	3	15	65
Jiutai2#	4	1	5	2	5	4	5	26	2	4	1	2	3	3	15	65
Qian'an1#	5	1	3	2	4	3	1	19	2	5	3	5	5	4	24	65
ChangchunSoutheast 3#	4	1	5	4	5	4	5	28	1	3	2	3	2	2	12	64
ChangchunSoutheast 4#	4	1	5	4	5	4	5	28	1	2	2	3	2	2	12	64
Longhua Changchun4#	4	1	5	4	5	4	5	28	1	2	3	2	2	2	12	64
Shuangliao1#	4	2	3	2	5	4	1	21	4	3	2	4	4	4	21	64
Shuangliao2#	4	2	3	2	5	4	1	21	4	3	2	4	4	4	21	64
Huaneng Changchun1#	4	1	5	4	4	5	3	26	2	3	2	3	2	2	14	63
Huaneng Changchun2#	4	1	5	4	4	5	3	26	2	3	2	3	2	2	14	63
Shuangliao3#	4	1	5	2	5	4	5	21	3	3	2	4	4	4	20	63
Shuangliao4#	4	1	5	2	5	4	5	21	3	3	2	4	4	4	20	63
SPIC Baicheng1#	3	2	5	4	4	3	1	22	2	3	1	3	3	5	17	60
SPICBaicheng 2#	3	2	5	4	4	3	1	22	2	3	1	3	3	5	17	60
Hunjiang2nd 1#	1	4	3	2	3	2	5	20	2	2	3	4	5	3	19	60
Hunjiang2nd 2#	1	4	3	2	3	2	5	20	2	2	3	4	5	3	19	60

Shuangliao5#	4	2	3	2	5	4	1	21	1	4	1	3	3	5	17	59
LonghuaYanji3#	3	5	3	4	3	3	3	24	1	2	3	2	2	2	12	57
LonghuaYanji 4#	3	5	3	4	3	3	3	24	1	2	3	2	2	2	12	57
Jiutai3#	4	1	5	2	5	4	5	26	1	4	1	1	1	1	9	57
Jiutai4#	4	1	5	2	5	4	5	26	1	4	1	1	1	1	9	57
Baicheng5#	3	2	5	4	4	3	1	22	1	4	1	1	1	1	9	50
Baicheng6#	3	2	5	4	4	3	1	22	1	4	1	1	1	1	9	50
SPIC Baicheng2nd	3	2	5	4	4	3	1	22	1	4	1	1	1	1	9	50
Changshan10#	4	1	5	2	3	3	1	19	1	4	1	2	1	3	12	49
SPIC Baicheng2nd	3	2	5	4	4	3	1	22	1	2	1	1	1	1	7	47
Baishan1#	1	4	3	2	3	2	3	18	2	1	2	3	2	2	12	47
Baishan2#	1	4	3	2	3	2	3	18	2	1	2	3	2	2	12	47

Appendix Ⅵ: Estimation of coal power utilisation hours of Jilin province under different scenarios during 13th FYP

<table>
<tr><th colspan="2" rowspan="2">Power Supply</th><th colspan="5">Planning capacity(MW)</th><th rowspan="2">Utilisation hours (Actual situation)</th></tr>
<tr><th>2016</th><th>2017</th><th>2018</th><th>2019</th><th>2020</th></tr>
<tr><td colspan="2">Hydropower</td><td>3490</td><td>3570</td><td>4200</td><td>4800</td><td>4800</td><td>1901</td></tr>
<tr><td colspan="2">Pumped storage</td><td>300</td><td>300</td><td>300</td><td>300</td><td>1700</td><td>600</td></tr>
<tr><td colspan="2">Wind</td><td>5264</td><td>5633</td><td>6027</td><td>6449</td><td>6901</td><td>1519</td></tr>
<tr><td colspan="2">Solar</td><td>301</td><td>436</td><td>561</td><td>656</td><td>726</td><td>1400</td></tr>
<tr><td colspan="2">Biomass</td><td>336</td><td>475</td><td>610</td><td>625</td><td>655</td><td>4500</td></tr>
<tr><td rowspan="3">Coal</td><td>Zero growth</td><td>18627</td><td>18627</td><td>18627</td><td>18627</td><td>18627</td><td rowspan="9">NA</td></tr>
<tr><td>Half growth</td><td>18627</td><td>18627</td><td>18977</td><td>22162</td><td>22162</td></tr>
<tr><td>Full growth</td><td>18627</td><td>18627</td><td>19327</td><td>25697</td><td>25697</td></tr>
<tr><td colspan="2" rowspan="2">Total electricity demand (GWh)</td><td>2016</td><td>2017</td><td>2018</td><td>2019</td><td>2020</td></tr>
<tr><td>67482</td><td>69844</td><td>72288</td><td>74818</td><td>77437</td></tr>
<tr><td colspan="2">Coal power energy</td><td>50975</td><td>51814</td><td>51679</td><td>52227</td><td>54207</td></tr>
<tr><td rowspan="3">Coal power hours</td><td>Zero growth</td><td>2737</td><td>2782</td><td>2774</td><td>2804</td><td>2910</td></tr>
<tr><td>Half growth</td><td>2737</td><td>2782</td><td>2723</td><td>2357</td><td>2446</td></tr>
<tr><td>Full growth</td><td>2737</td><td>2782</td><td>2674</td><td>2032</td><td>2109</td></tr>
</table>

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