nzec
carbon capture & storage

Energy and Emission Scenarios in Jilin Province

WP2 Report

Energy Research Institute

Table of contents

1. Background

In order to support the analysis for Carbon Capture & Storage (CCS) potential in China, a case study for Jilin province was undertaken. Assessment of future power generation, and hence energy and emission scenarios, in Jilin province is integral to analysis of CCS potential. Therefore, the objective of this report is to present energy and emission scenarios up to 2030 based on a quantitative modelling study. Here we focus on the power generation sector and present the picture focusing on coal fired power generation which is most promising sector for CCS application. Due to lack of information on CCS utilization, the potential for CCS in power generation sector is presented based on previous published report from IPCC and other sources. Therefore the key issue we consider here is the possible future pathway for power generation by different sources in Jilin Province. Once good information on CCS becomes available, it will be easier to understand the potential for CCS in power generation sector in Jilin Province.

The report is presented is in 3 sections. Firstly Jilin province is described in terms of its population, energy use and resources including some discussion of the government initiatives used to restructure the energy mix of the province. Next the approach to the modelling used in this study to model Jilin's future energy from 2005 to 2030 is presented. Finally the potential for CCS in Jilin is considered on the basis of policy initiatives against a BaU scenario. Further data and parameters used in the modelling are provided in the Appendix.

2. Jilin Province in Brief

2.1 Jilin's geography and natural resources

Jilin province is located in the central part of Northeast China, adjoining Heilongjiang Province in the north, Lianing Province in the south, and the Inner Mongolian Autonomous Region in the west. The total area in Jilin Province is 187,400km^2, which account for 2% of the China's total land area.

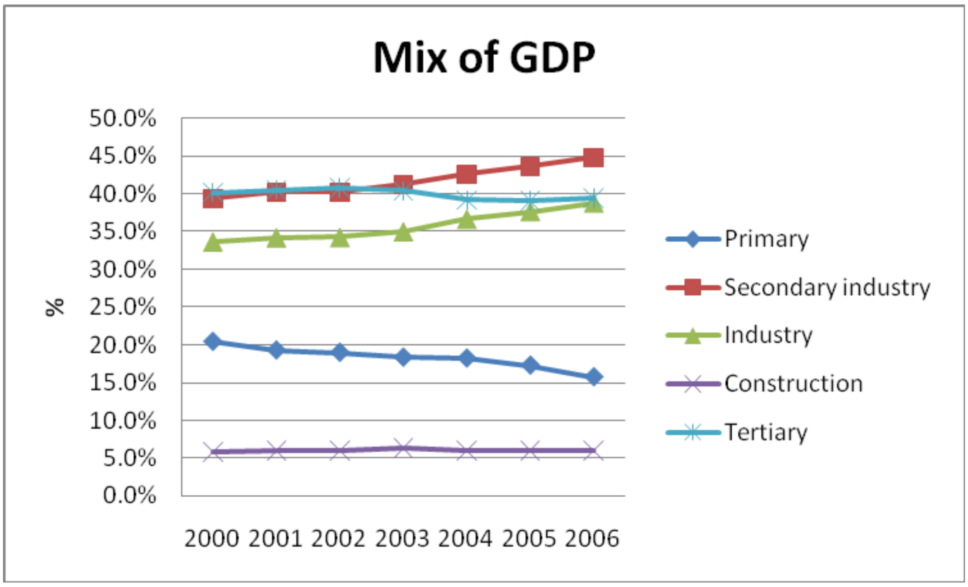
2.2 Population and Urbanization

In 2006, the population in Jilin province was 26.79 million, having an annual growth rate of 0.58% from 1990 when the population was 24.4 million. The area has also increased its urbanization from 39% of the population in urban areas in 1990 to 45% in 2006.

2.3 GDP

Jilin's GDP in 2007 was 522.6 billion yuan (US$68.7 billion) and ranks 22nd in the country. Its annual growth rate from 1990 to 2006 was 10.4% from 42.5 billion yuan (US$5.6 billion) in 1990. The GDP per capita was 19,168 yuan (US$2,520) in 2006. Among the economic components, primary industry, second industry and tertiary industry account for 15.7%, 44.8% and 39.5% in 2007, respectively. The share of secondary industry is lower than the national secondary industry's share, whilst the share of tertiary industry is similar to the national situation. However, the share of secondary industry has been increasing in recent years (see Figure 1). This reflects an improvement in economic growth, but this has been accompanied by an increase in the province's energy intensity.

Figure 1 Mix of GDP in Jilin province



Jilin's main industries are automobile production, petrochemicals, and agriculture. First Auto Works is China's largest carmaker and is based in Changchun (the capital of the province). Jilin also is one of China's top producers of corn. In 2003, the Central Government launched the "Revitalize the Northeast" plan, in part to further reform and privatise state-owned enterprises, which continue to dominate Jilin's economy.

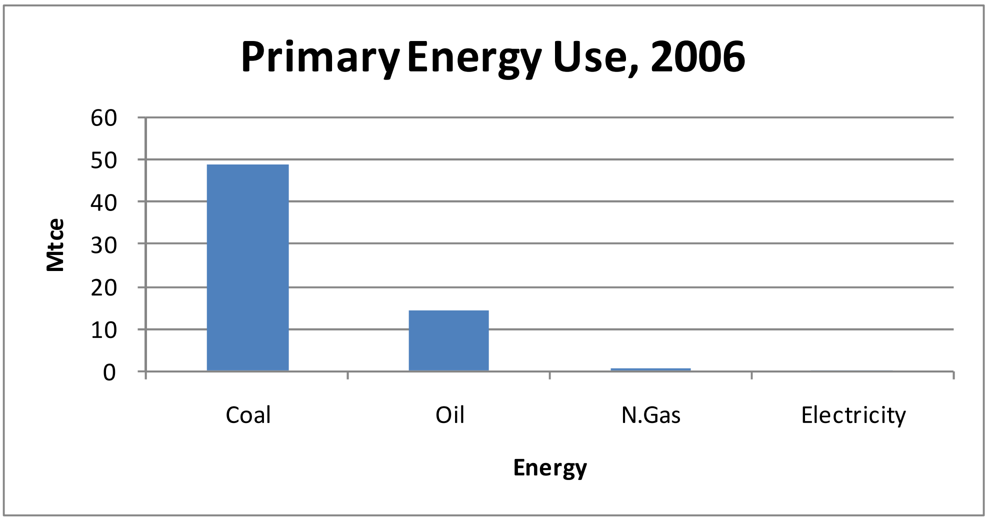
Jilin Province has a very solid industrial base with more than 14,000 industrial enterprises and six dominant industries, which are engineering, petrochemicals, pharmaceuticals, food, metallurgical and forestry. Jilin leads the country in its production of automobiles, railway cars, tractors, ferroalloies, carbonic products, timber, sugar, crude oil, vegetable oil and non-mineral products.

2.4 Energy Use

Commercial energy use

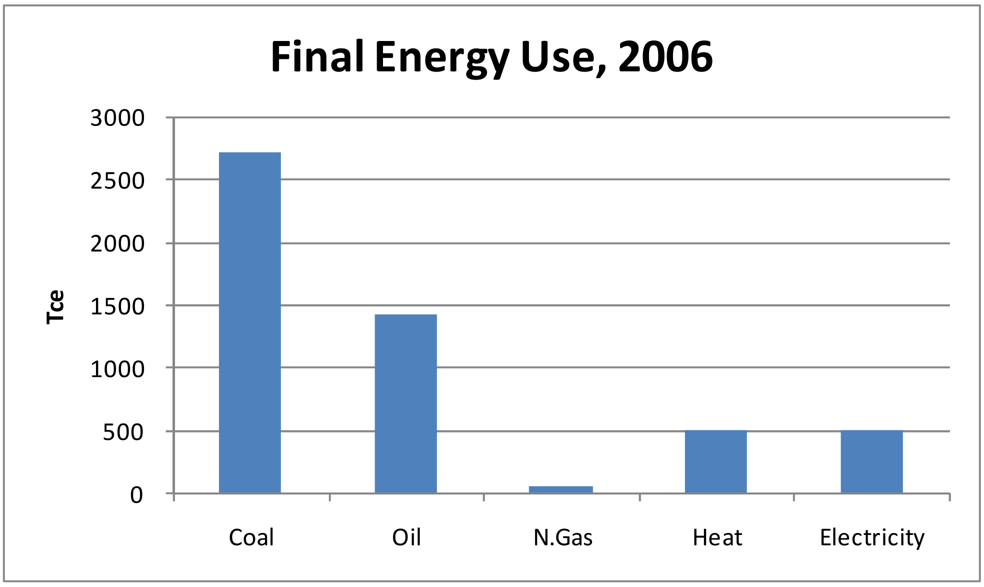
In 2006, primary energy use in Jilin was 65.9 Mtce, having risen from 34 Mtce in 2000. Coal dominates primary energy use as shown in Figure 2. Local energy production was 30.3 Mtce, with 20.6 Mtce from coal and 8.9 Mtce from crude oil. Imported energy was 39.3 Mtce, with 30.9 Mtce from coal and 4.8 Mtce from crude oil. Exported energy was 4.58 Mtce (The Overall Energy Balance Sheet for Jilin Province is presented in the Appendix).

Figure 2 Primary energy use in Jilin province



Total final energy use was 54.15 Mtce in 2006, with secondary industry responsible for 70%, 16.1% for tertiary industry, and 10.3% for the residential sector. Among secondary industries, those in the chemical sector are the biggest energy user, followed by the building material sector, and non-ferrous sector, with energy use of 19.07 Mtce, 5.66 Mtce, and 5.65 Mtce, respectively. Coal accounts for 50.8% of total final energy use, oil 29%, electricity 9.5%, heat 9.4% and natural gas 1.3% (see Figure 3).

Figure 3 Final energy use in Jilin province



Traditional energy use

Located in the world-famous 'black land belt' known for its rich soil, Jilin Province is one of the major grain producing areas in China and thus possesses rich crop stalk resources. Each year 3.57 million ha. planting area is utilised producing 45.36 million tonnes of crop stalk in total, of which corn stalks account for 38.49 million tonnes equal to 20.36 Mtce.

Historically, a large amount of crop stalk has simply been burned without being utilized effectively. As a result, not only is this natural resource wasted, but also the burning of crop stalks causes air pollution that negatively affects the health of the rural population. With the development of the rural economy, the rural population are becoming better-off and are eager to change the traditional fuel structure to improve their quality of life including getting rid of the old cooking method of burning stalks. The development and utilization of biomass energy is one of the few effective ways that can meet the needs of the rural population and in doing so help bring about a change in the rural energy structure.

The Jilin Government has attached great importance to the development of biomass energy, considering it a showcase project that bears a special meaning for the development of a geologically and environmentally balanced economy. The provincial government has set up the "Jilin Province Rural Biomass Energy Development Leadership Group" with 10 departments involved including the Jilin Province Planning Committee, Jilin Province Finance Department, and Jilin Province Environment Protection Agency. In close cooperation with the Energy Working Group of China Council of International Collaboration on Environment and Development (CCICED) and with the support of related departments, Jilin Province took less than two years to build two biomass gasification demonstration projects with different technological processes, different sizes and different methods of operation.

By the end of 2006, energy use for cooking in rural households was 93.4% straw (in 3.35 million households), 4.7% using coal (0.168 million households), 1.7% using coal gas or natural gas (60,716 households) and the remaining households use biogas (273) and electricity (6,623). Biomass has already successfully been turned into gas in Jilin and other Chinese provinces to provide a clean cooking fuel for rural villages. However, these projects have not been economically attractive because they generally only operate for about six hours each day, which is not sufficient to recover the capital cost. There is one pilot phase project which will expand the plant incrementally to meet the village's needs for electricity and heat – in an area where annual temperatures average just 2.5°C – and sell surplus power to the national grid. The added revenues from the expanded operation of the plant will make it economically attractive.

2.5 Energy supply

By the end of 2005, there were 7 coal mines administrated by the provincial government, with 42 coal mine wells with a total capacity of 15.27mt/year. Additionally, there are 431 village and township coal mines with an actual capacity 15.96 mt/year. The total output of coal was 25.77

mt in 2004. It is expected that coal output will be 30 mt by 2010.

In Jilin Province the identified oil resource is 2.63 billion tonnes. By the end of 2005, the accumulated oil reserve was 1.03 billion tonnes, the natural gas resource was 971.9 billion m^3, with a further reserve of 24.9 billion m^3 identified. Crude oil production capacity is 5 million tonnes/year and in 2006 oil refinery production was 6.84 million tonnes, crude output was 6.21 million tonnes, and natural gas 241 million m^3.

2.6 Power generation

By the end of 2006, installed capacity of power generation is 11.1GW, of which hydro power is 3.87GW, and wind power 200 MW. Total electricity output is 45.5 TWh. The Jilin Grid includes four parts: Changchun, Jilin, Sipin and Baidong sub-grid, with a transmit line voltage of 220KV. It is planned that by 2010 the total installed power capacity will be 16.85 GW, of which hydro power is 4.27GW and wind at 880MW. A recent wind resource survey (ref) shows there is wind potential for power generation of up to 67GW. By the end of 2008, installed capacity of wind power generation in Jilin province is 1180MW which is already above the target of 11th Five Year Plan for 2010, and it is planned to be 10GW by 2020.

3. Methodology used for this study

3.1 Methodology framework

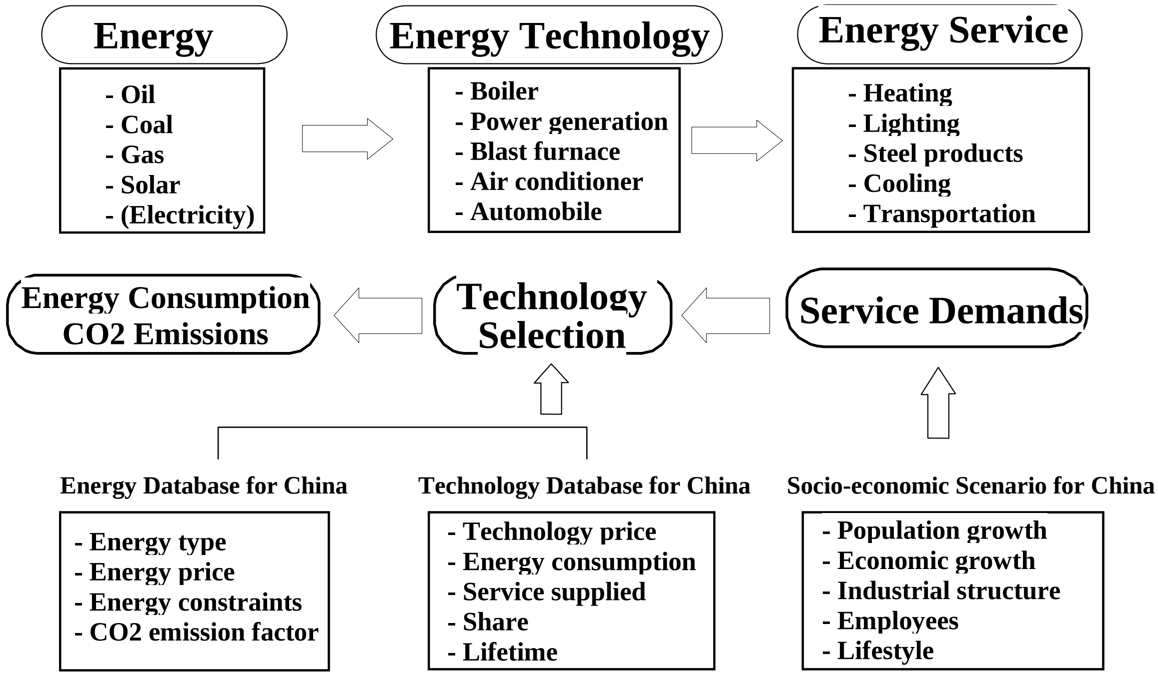
The IPAC-AIM/Technology model is used to present energy and emission scenarios for Jilin province. The IPAC-AIM/technology model has been used for the national energy and emission scenario analysis as well as several regional scenario analyses including Beijing, Guang Dong, and Hong Kong. This study adopts a similar framework as these previous studies.

The timespan of this study is 2005 to 2030 to relate to the local energy planning period and issues within the climate change plan. The base year is 2005 and CO_2 is the main greenhouse gas (GHG) covered.

3.2 Models

The IPAC-AIM/Technology model is a single-region model for China, developed based on the AIM/end-use model (AIM Project Team 1996; Hu, Jiang, and Liu, 1996; Jiang and others 1998; Hu and Jiang 2001). This model includes three modules (energy-service demand projection, energy-efficiency estimation, and technology selection) as shown in Figure 4. Demand is divided among the industrial, agricultural, service, residential, and transportation sectors, which are further divided into subsectors. On both the demand and supply sides, more than 400 technologies are considered, including existing technologies as well as potential technologies that may be used in the future. The model searches for the least-cost technology mix to meet the given energy-service demand, while several constraints could be given for the least cost choice including resource availability, emission limitation etc. The model makes technology choices based on least cost, which could lead to underestimations of mitigation cost. The most up-to-date information on these technologies was collected from a large number of published sources, as well as by consulting with experts directly, on energy service demand, technology parameters, and technology progress potentials. The policy options can be simulated by the model to see the impacts of different policies. More information on the model including key factors and policies that can be analysed is given in the Appendix.

Figure 4 Structure of IPAC-AIM/technology model (Jiang et al, 1998)



4. Energy and Emission scenarios for Jilin

4.1 Key assumptions

Two scenarios are examined to analyse future energy demand and emissions in Jilin Province:

- *Baseline scenario*: This scenario gives a basic trend to describe future economic activities, based on the historical trend and local planning. This is consistent with the national baselines scenario. It reflects existing policies and measures, and considers current efforts of the Chinese Government to increase energy efficiency and control GHG emissions.
- *Policy scenario*: Various energy and emission-control policies are assumed for this low-demand scenario, which reflects energy supply and environmental constraints. A policy package will be implemented, including the optimization of the economic structure, decrease in the share of high energy consuming industries in the economy; the wide dissemination of current energy conservation technology; and the aggressive diversification of the electricity generation mix. By 2030, the energy efficiency of major high energy consuming industries would reach or surpass the advanced level of developed countries, and new building construction would need to reach a high energy efficiency standard. In general, this would reflect a shift towards highly efficient and clean production; and aggressive standards to encourage a public focus on energy efficiency in the home and the workplace.

According to the provincial plan, GDP is projected, by the 11th Five Year Plan, to grow at an annual rate of 12% from 2005 to 2010. The regional government also made projections for economic development up to 2020, which is 8.7% from 2010 to 2020. There is a lack of research for GDP growth after 2020 for Jilin province, thus we made an assumption based on the national economic development, and set it at 6%. All the growth rates are marginally higher than national average. GDP Growth rates and mix between industries are shown in Tables 1 and 2 respectively.

Population data comes from government planning figures for 2020, and are based on the national population projection for 2030 (see Table 3).

Sector based key parameters are presented in Tables 4 and also in Appendix, based on local planning and the research team's understanding.

Table 1 GDP for Jilin province

	2000-2005	2005-2010	2010-2020	2020-2030
GDP Growth Rate	11.40%	12.00%	8.70%	6.70%

Table 2 GDP and mix in Jilin province

	2003	2005	2010	2020	2030
GDP, billion yuan	195.1	335	590	1359	2598
Mix, %					
Primary Industry	20.4	17.3	14	11	8
Secondary Industry	39.4	43.7	48	50	45
Tertiary Industry	40.2	39.1	38	39	47

Table 3 Population in Jilin province

		2005	2010	2020	2030
Total population	Million	26.69	26.96	27.23	27.50
Share of City	%	0.53	0.55	0.60	0.66
City Population	Million	14.02	14.83	16.34	18.15
Rural population	Million	12.67	12.13	10.89	9.35
City HH[1]	Million	4.63	5.24	6.05	6.98
Rural HH	Million	3.20	3.37	3.30	3.02

Energy intensive products account for more than 50% of total final energy use in Jilin. Therefore the forecast of energy intensive products is very important for future energy use scenarios. The forecast of energy intensive products comes from different sources:

- Local planning: there are some provincial government planning for key economy sectors, which present development targets for products output.
- Historical trends
- National energy intensive products output. This is the study in IPAC modelling team, national scenario for energy intensive sector were analyzed, and distribution to each province was reported.

Table 4 Assumptions about energy-intensive products in the model, baseline scenario

		2005	2010	2020	2030
Steel	Mt	5.33	11	14	15
Cement	Mt	25.24	45	61	70
Glass	Mt	7.69	15	19	19
Ethylene	Mt	0.75	1.5	3	3
Refinery	Mt	8.81	16	19	20
Plastic	Mt	5.51	9.42	13.29	15.43
Paper	Mt	0.5	0.9	1.3	1.8
Vehicle	Million	0.63	1.2	1.8	2.5

[1] HH - Household

Some key parameters in the household and service sector are given in a more detailed way. The number of households in urban and rural areas is a key driving force. Energy service in households is given by various activities which use energy in the home, such as cooking, lighting, space heating, space cooling etc. Ownership of electrical appliances, expansion of using time (such as time spent watching TV), expansion of using intensity (such as higher temperature for space heating) are key parameters setup in the model to decide energy service demand. In order to understand the service demand, we use an index to show the future trend.

The policy options considered were defined based on the potential policy in Jilin and possible technology trends (Jiang et al, 2008; Jiang et al, 2009;) (see Table 5). Many of these policies are already in place but need further implementation and stricter standards, such as technology-efficiency standards, renewable-energy targets and fiscal policies, energy targets, and so forth. Some new policies, including taxes, are also designed.

Table 5 Policy options used in the modelling study

Policy option	**Explanation**
Technology-promotion policy	Efficiency of end-use technology increases as a result of new technologies
Energy-efficiency standard for buildings	New buildings reach 75 % energy efficiency standard in 2030
Renewable energy development	Policy includes subsidy for wind power and biomass power generation, as well as government support on village biogas supply system
Energy tax	Vehicle tax introduced by 2005; energy tax introduced by 2015
Public transport	Share of traffic volume by urban public transport will be 10–15 % higher in 2030 than 2000
Increases in transport efficiency	High fuel-efficiency vehicles, including hybrid vehicles, compact cars, and advanced diesel cars, widely used
Increases in power generation efficiency	Average efficiency of coal-fired power plants increases to 40 % by 2030
Natural gas incentive	Natural gas supply enhanced, technology localized to reduce cost
Nuclear power development	Target setting in National promotion program, enhanced government investment, technology development

Source: Jiang et al, 2006

4.2 CO_2 capture and storage technologies

The CCS technologies used in the model are based primarily on the findings from the IPCC Special Report on CCS (IPCC, 2006). CCS was applied to super critical, ultra-super critical units, and IGCC.

Based on the IPCC findings, costs of retrofitting CCS to existing installations vary. Industrial sources of CO_2 can more easily be retrofitted with CO_2 separation, but integrated systems would need more profound adjustment. In order to limit future retrofit costs, new plant designs could take future CCS application into account (see Table 6).

Table 6 Costs of CCS (taken from IPPC, 2006)

	NGCC (US$/kWh)	PC (US$/kWh)	IGCC (US$/kWh)
Without capture	0.03 - 0.05	0.04 - 0.05	0.04 - 0.06
Power plant with capture and geological storage	0.04 - 0.08	0.06 - 0.10	0.05 - 0.09
Power plant with capture and EOR	0.04 - 0.07	0.05 - 0.08	0.04 - 0.07

The NZEC project also provided cost data for CCS (see Table 7). This data was used in the model in combination with IPCC data.

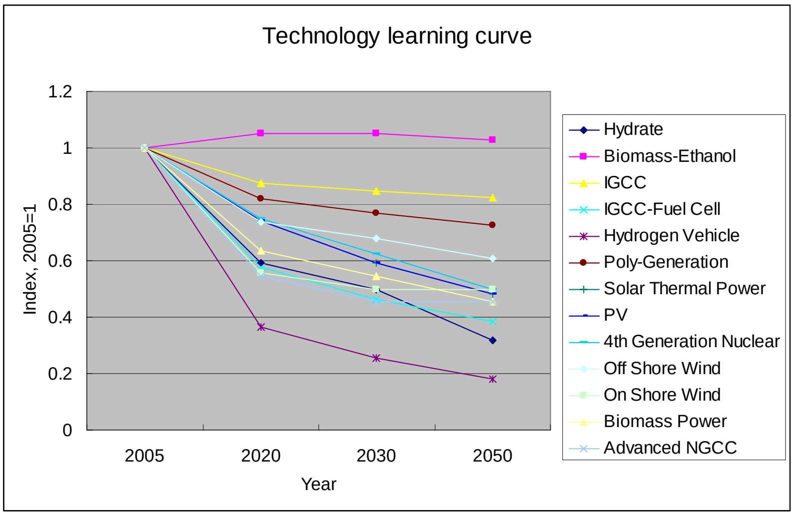
Table 7 CO2 capture cost for coal fired power plants from NZEC project WP3

Category	%CO_2 captured	Size MW (nominal) without capture	Start year	Investment cost multiplier for capture	Investment cost (RMB/kW net) low	Investment cost (RMB/kW net) high
Coal without	0%	1000	2005		5000	5000
Coal + CCS	90%	1000		1.6	8000	10000
Coal without	0%	1000	2020		4500	4500
Coal + CCS	93%	1000		1.5	6750	8438
Coal	0%	1000	2030		4500	4500

without						
Coal + CCS	95%	1000		1.4	6300	7875
Coal without	0%	1000	2050		4500	4500
Coal + CCS	98%	1000		1.3	5850	7313

In the model, the learning curves for key technologies are presented including IGCC (see Figure 5). We assume there will be no cost reduction for super critical and ultra-super critical unit by 2030, due to very low cost in China currently (Jiang et al. 2009). This is but one possibility and other variants are considered elsewhere in the NZEC project, such as in WP3.

Figure 5 Cost learning curve for selected key technologies



China has worked on IGCC since 1978, and listed it into national key project for technology development. However, owing to historical reasons, scientific research institutes and equipment manufacturers have not shown much enthusiasm. This is due to IGCC being a largely untested technology, and local manufacturers already have strong competitiveness on super critical units and ultra-super critical units. As such the IGCC development has progressed relatively slowly.

The State Power Corporation had intended to build a demonstration IGCC power station in Yantai, Shandong province. However the high cost of having to import the necessary technology, the likelihood that benefits of deploying the technology on efficiency improvement would not be realized in the short term, combined with national power shortage at that time, meant the project was cancelled.

More recently, with the continued deterioration of the environment and increasing emphasis on of “energy saving and pollution emission reduction”, China has attached renewed importance to IGCC and there has been some further R&D undertaken. At the end of 2005, China

Huaneng Group Co. made a proposal of "Clean Coal Electricity Strategy", and initiated the GreenGen Project, which focuses on IGCC development. In June 2009, this first Chinese IGCC power plant was approved by NDRC and construction was started. Since 2006, many other proposals for the application of IGCC have been made by several leading corporations. At present there are nearly 20 IGCC power plant projects in the pipeline awaiting government approval. However, the NDRC has concerns regarding high capital costs and associated high costs of electricity generation. Consequently, the introduction of IGCC would require a significant pricing subsidy, which is not yet thought justified.

IGCC systems utilize the efficiency and low capital cost advantages of a CCGT by first gasifying coal or other fuel. Gasifiers are usually oxygen blown and are at the early commercial stage. Coal and difficult liquid fuels such as bitumen and tar can be used as feed stocks. The potential efficiency of IGCCs is around 58%, based on the latest CCGTs of 65% efficiency. With continuing development in hot gas cleaning and better heat recovery as well as the continuing development of CCGTs, commercially available coal or wood-fired IGCC power stations with efficiencies over 60% may be feasible at some point in the future. IGCC also has potential for further application for poly-generation which could provide higher efficiency. However barriers for IGCC include the high initial cost and system complexities. IGCCs currently in operation in the world continue to suffer from poor reliability and are not favoured by power generation companies. Consequently, the focus remains on SC/USC units, which offer far better energy security and have the potential at least to reach over 50% efficiency.

In addition to the potential high efficiencies, IGCC offers one of the more promising routes to CO_2 capture and storage by converting the gas from the gasifier into a stream of H_2 and CO_2 via a shift reaction. The CO_2 can then be removed for storage before entering the gas turbine. The resultant stream of H_2 could be used as the primary fuel in a gas turbine or in fuel cells. Recently, large amounts of investment were given to fuel cell R&D. The internal fuel is hydrogen, but some fuel cell types can use fuels such as CO, methanol, natural gas or even coal if externally converted to hydrogen at the plant via gasification and steam reforming or partial oxidation. Alternatively, some fuel cell designs perform the hydrogen conversion step internally as an integral part of the technology. This provides good basis for second generation of IGCC with fuel cells.

Based on the study of long-term emissions trends for China, a role of CCS is identified to reach a low carbon future. Considering the efficiency loss association with CCS application, the potential higher efficiencies offered by IGCC compared with super critical units, means IGCC is likely to play an important role in CCS utilization in China in the long-term.

Based on the above information, we give simple assumption for CCS application in Jilin province:

- No limitation on use of CCS before 2020 although there is likely to be small demand for CCS at that time, with the focus on the use of EOR rather than storage.
- By taking consideration of cost and efficiency, we assume all newly installed IGCC power plants could be equipped with CCS.

- In the policy scenario with a push towards greater utilization of CCS in Jilin province, we also assume some application of CCS for super critical units and ultra-super critical units, however due to the large uncertainty for this option, we only assume limited super critical and ultra-super critical units will be equipped with CCS.
- Due to limited information, this is only given by scenario, with thinking about possible efforts the government might make towards a low carbon future. Here we assume that by 2020, 20% of super critical units will be equipped with CCS, 40% of ultra-super critical equipped with CCS. By 2030, 40% super critical units and 80% of ultra-super critical units equipped with CCS.

According to the IPCC data, the capture efficiency for CO_2 is in the range of 81-88% for newly constructed PC plants, and 81-91% for new IGCC, with potential for 95%. By taking into account likely future progress we assume the capture rate for IGCC could reach 95%, and 80% for super critical (SC) and ultra super critical (USC) units which includes existing power plants. The reason for the lower capture rate for SC and USC units is because there is concern that the storage capacity in the region will not be sufficient to deal with all the emissions from the large commercial scale SC/USC units while it may be adequate to deal with the CO_2 captured from what will be much smaller scale IGCC plants.

The main uncertainties about CCS potential in Jilin province include the size of storage, potential of CCS with SC and USC, and the cost reduction. If there is a lower energy penalty for CCS on SC and USC units, the size for CCS utilization in Jilin province could be bigger. In order to understand these data, an early pilot phase project on CCS is very essential to present more concrete information on CCS.

5. Energy and Emission Scenarios in Jilin

5.1 Energy scenarios

By using the IPAC-AIM/Technology model, and the above assumptions, the results are presented in the following tables (more extensive results are presented in the Appendix, while further information on the AIM model is available via previously published studies, see References).

We can see that primary energy demand in the baseline scenario keeps on increasing and could reach 156 Mtce in 2020 and 187 Mtce in 2030 (see Table 8). The annual growth rate from 2000 to 2030 is 4.5 % while the energy elasticity of GDP is 0.53. Coal will be the major primary energy source in Jilin in future (127 Mtce in 2030), accounting for 68% of the total energy demand; of which 57% will go to power generation and heat supply (Table 9 and Figure 6). There is a rapid increase in natural gas demand in Jilin, with its share in total primary energy use increasing from 1% in 2005 to 4% in 2030 (an average annual growth rate of 9.4%).

The policy scenario shows a strong effect on energy demand reduction, as well as CO_2 emission reduction. Compared with the baseline scenario, energy demand declines by almost 27% in 2030 (see Tables 10 and 11 and Figure 7). By exploring the policy options it is found there is big pressure to apply these policy options in order to reach the lower energy demand scenario, and also they need to be introduced at an early stage because of “lock-in” effects of energy technologies.

Table 8 Total Primary energy demand, BaU scenario, Mtce

	Coal	Oil	N.Gas	Electricity	Total
2006	48.7	14.5	0.8	0.1	64.1
2010	87.7	27.5	1.8	0.2	117.2
2020	113.2	38.4	3.9	0.7	156.2
2030	127.9	50.0	7.0	2.4	187.2

Table 9 Final energy demand, BaU scenario, Mtce

	Coal	Oil	N.Gas	Heat	Electricity	Total
2006	27.2	14.3	0.7	5.1	5.1	52.3
2010	49	25	1.5	8.1	9.9	87.4
2020	60	34.7	3.4	11.3	19.4	128.8
2030	55.2	46.4	4.8	14.8	33.9	155.2

Figure 6 Final energy demand – BAU Scenario

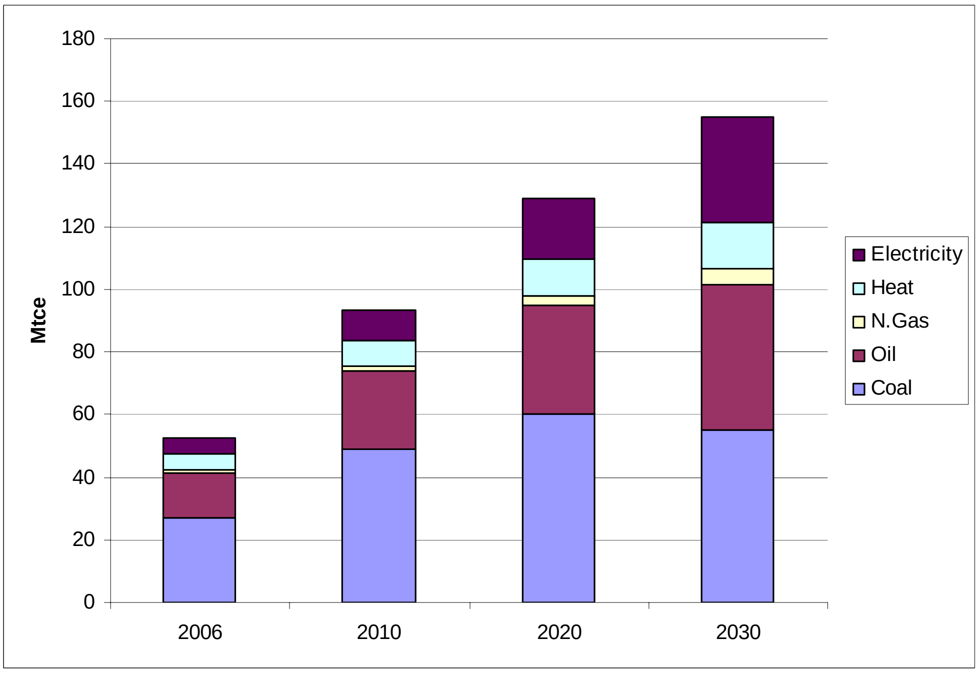


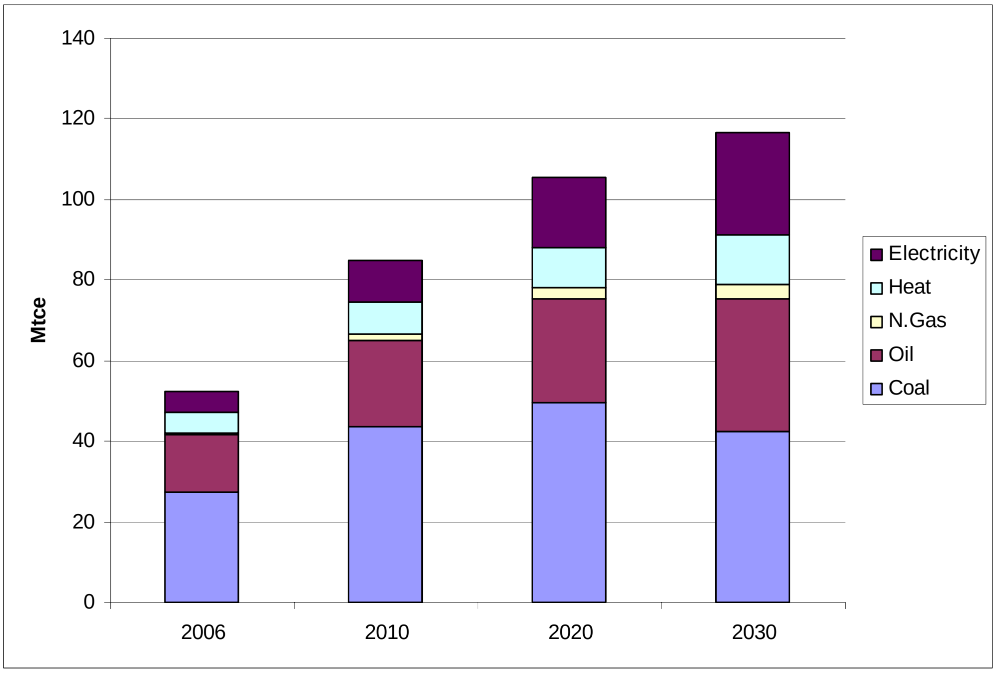
Table 10 primary energy demand, policy scenario, Mtce

	Coal	Oil	N.Gas	Electricity	Total
2006	48.7	14.5	0.8	0.1	64.1
2010	78.0	23.1	1.7	0.6	103.4
2020	89.7	28.9	4.0	3.8	126.4
2030	87.9	34.1	8.4	7.9	138.3

Table 11 Final energy demand, policy scenario, Mtce

	Coal	Oil	N.Gas	Heat	Electricity	Total
2006	27.2	14.3	0.7	5.1	5.1	52.3
2010	43.5	21.6	1.5	8.1	10.1	79.2
2020	49.5	25.9	2.7	9.8	17.6	105.4
2030	42.6	32.6	3.6	12.5	25.2	116.4

Figure 7 Final energy demand - Policy Scenario



5.2 Emission scenarios

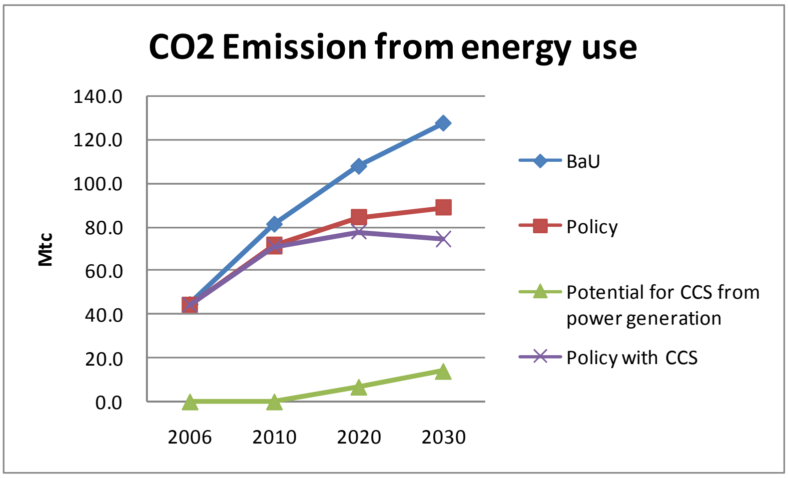
Based on the energy use, CO_2 emissions were calculated, and given in Table 12 and Figure 8. Potential for CCS is given here by following the assumptions in chapter 4.2.

Table 12 CO2 emissions in Jilin province from energy use, Mt-C

	BaU	Policy	Potential for CO_2 capture from power generation
2006	44.3	44.2	0.0
2010	81.0	71.1	0.0
2020	107.4	84.3	6.8
2030	127.1	88.4	14.1

NB. The CO_2 storage capacity in the province is not yet known. As this will ultimately determine the CCS potential, it is important to recognise that any estimates of CCS potential in the province cannot yet be substantiated.

Figure 8 CO2 emissions in Jilin province from energy use



5.3 Power generation

Based on the energy scenario, power generation scenarios are given in the following tables.

Table 13 Power generation, BaU, TWh

	Coal fired	Oil fired	N.Gas	Hydro	Nuclear	Wind	Solar	Bio	Total
2005	38.6	1.1	0.5	5.2	0.0	0.0	0.0	0.0	45.5
2010	77.2	1.3	1.8	9.0	0.0	0.8	0.0	0.2	90.3
2020	145.1	1.8	9.7	16.8	0.0	3.2	0.0	0.5	177.2
2030	242.8	2.2*	27.3	26.4	0.0	10.2	0.0	1.2	310.1

*Assumes low quality oil resource is available for use in power generation.

Table 14 Coal fired power capacity, BaU, MW

	Small Coal	Large Coal Unit	Super Critical	US-Critical	IGCC
2005	2597	4304	371	0	0
2010	1715	7563	4322	1389	0
2020	1451	7700	14512	4887	0
2030	0	12140	23268	13657	0

Table 15 Power generation, Policy Scenario, TWh

	Coal fired	Oil fired	N.Gas	Hydro	Nuclear	Wind	Solar	Bio	Total
2005	38.6	1.1	0.5	5.2	0.0	0.0	0.0	0.0	45.5
2010	76.3	1.3	1.8	9.2	0.0	3.0	0.0	0.4	92.0
2020	117.9	1.6	8.8	15.3	0.0	14.5	0.6	1.9	160.6
2030	136.0	1.6*	20.3	19.6	18.4	27.7#	2.3	4.6	230.5

*Assumes low quality oil resource is available for use in power generation

#Assumes a larger grid linking with the North-East grid to address problems with intermittent nature of wind-power

Table 16 Coal fired power capacity, Policy scenario, MW

	Small Coal	Large Coal Unit	Super Critical	US-Critical	IGCC
2005	2597	4304	371	0	0
2010	1695	7474	4271	1373	0
2020	917	7459	6496	3970	4331
2030	0	6233	6516	7649	7083

6. CCS potential in power generation sector in Jilin Province

There is a lack of good information on the technical and cost information for CCS utilization in China. In this study we calculated the potential for CCS in power generation based on information from IPCC and other relevant studies (including NZEC WP3 data).

Here we assume all newly installed IGCC power plants could use CCS, and modest deployment of CCS on super critical and ultra-super critical units. There is plenty of potential CO_2 storage in Jilin's oil fields, so we assume there is no limitation for carbon storage.

We only present the potential for CCS based on the policy scenario. The capacity for CCS is given in Table 17 and carbon abatement from CCS is given in Table 18. We assume 100% deployment of CCS on IGCC plants from 2020. This is consistent with the national low carbon scenario analysis for CCS utilization in China (Jiang, et al, 2009). In the Jilin scenario, we did not consider the additional capacity needed due to CCS utilization which will result in lower net power supply.

Table 17 CCS capacity, MW

	Small Coal	Large Coal Unit	Super Critical	Ultra Super Critical	IGCC
2005	0	0	0	0	0
2010	0	0	0	0	0
2020	0	0	1299	1588	4331
2030	0	0	2606	6119	7083

Table 18 Annual CO2 emission reduction, mt-C

	Small Coal	Large Coal Unit	Super Critical	Ultra Super Critical	IGCC
2005	0	0	0	0	0
2010	0	0	0	0	0
2020	0	0	1.2	1.4	4.2
2030	0	0	2.3	5.1	6.8

Findings and Conclusion

From this study we have the following findings:

- Coal fired power plants will continue to play an important role in the future of Jilin's power generation system. According to the scenario analysis, even in the policy scenario, coal fired power plants will have an installed capacity of 28GW by 2030, accounting for 51% of total installed capacity.
- This means there is big potential for capturing CO_2 in Jilin province but the extent to which this enables utilisation of CCS depends also on storage capacity. The preferred approach would be to inject the CO_2 into oil fields for EOR and subsequently for storage. The model results suggest that the amount of CO_2 that might be captured before 2030 is around 480 million tonnes. However, this depends in part on the technological progress of CCS. If the efficiency penalty to use CCS for super critical and ultra-super critical units is inside the adoptable range, the potential for CCS could be bigger. However, the uncertainties about storage capacity mean that further assessments of storage reservoirs are needed.
- If it turns out that the oilfields in Jilin Province do not offer adequate storage capacity for CO_2, the alternative would be storage in deep saline formations. Again, a full assessment of the storage capacity is needed.
- At present in China the preferred coal fired power plants are SC/USC, which have shown considerable advances in recent years. For the longer term, it has been assumed in this study that IGCC may offer an attractive alternative, both on high energy efficiency grounds and for CCS application. If this is to be a way forward, then IGCC would need to be fully promoted. This would need IGCC to start to be installed by 2010 otherwise there will be limited opportunities for China to go to very low carbon emission future in 2050 (Jiang et al, 2009). And as a pilot province on CCS, Jilin could take lead on application of IGCC and CCS, to help Jilin slow CO_2 emissions increases after 2020.
- By 2030, the scenarios show there will be around 7083MW IGCC power plants in Jilin province, which is around 20 IGCC units (mainly 250MW and 400MW units). This implies the majority of the newly installed coal fired power plants will be IGCC after 2010
- Before 2020 there could be 20 to 25 IGCC units, accounting for 18.7% of total installed coal fired power plants, and 52% of newly installed coal fired power plants capacity. However, this is a very optimistic scenario in view of the state of development of IGCC.
- There will be around RMB15billion increase for fixed cost from 2010 to 2020. The cost could be covered by higher efficiency profit, CDM, and internal aid with collaboration on climate change, together with local clear air initiatives.
- There still remains big uncertainty as to the cost of CCS utilization in Jilin, further study is necessary, to identify various cost for CCS in Jilin by doing detailed case study and technology feasibility.
- Early pilot phase of CCS is necessary and Jilin could be a good candidate for the pilot

phase CCS projects, but this is dependent on storage availability.

- The cost for CCS in Jilin could be covered by multi-lateral and bilateral collaborations, including China-EU, China-US clean energy program, and CDM project, plus Chinese government's pilot phase project.
- From the scenario analysis, a technology roadmap for CCS should be drawn-up, alongside a policy roadmap, which should be included in the 12th five year plan. Near term policy direction is crucial for Jilin to achieve a low carbon future by implementing CCS. There will be a rapid increase of coal fired power plants in the next 10 years, and so a near term policy to promote IGCC and CCS is crucial if it is decided that IGCC is the preferred technology option for use with CCS.
- The CCS potential scenario analysis should also be extended to energy intensive sectors in future.

References

AIM Project Team (1996) A Guide to the AIM/End-use Model, AIM Interim Paper, IP-95-05, Tsukuba, Japan.

China Year Book 2008 (2008) China Statistic Publishing House, Beijing

China Environment Year Book 2004 (2004) China Environment Year Book Editing Committee, Beijing

China Energy Year Book 2008 (2008) China Statistic Publishing House, Beijing

Hu X, Jiang K, Liu J (1996) Application of AIM/Emission Model in P.R. China and Preliminary Analysis on Simulated Results, AIM Interim Paper, IP-96-02, Tsukuba, Japan.

IPCC (2005) IPCC Special Report on Carbon Dioxide Capture and Storage, Cambridge Press

Jiang K, Hu X, Matsuoka Y, Morita T (1998) Energy Technology Changes and CO2 Emission Scenarios in China. Environment Economics and Policy Studies 1:141-160.

Jiang, K., and H. Xiulian (2006) Energy Demand and Emission in 2030 in China: Scenarios and Policy Options, Environment Economics and Policy Studies Vol.7, No.3:233-250

Jiang Kejun, Hu Xiulian, Zhuang Xing, Liu Qiang, Zhu Songli (2008) China's Energy Demand and Emission Scenarios by 2050, Climate Change Research Review, Vol 4, No.5: 296-302

Jiang Kejun, Hu Xiulian, Liu Qiang, Zhuang Xing, Liu Hong (2009a) China's Low Carbon Economy Scenario, In Low Carbon Economy Development in China, China Science Publishing House, Beijing (under editing)

Jilin Statistical Yearbook 2008 (2008) Jilin Statistical Yearbook 2008, China Statistic Publishing House

Appendix – Data tables

Jilin Province - data

Population and Its Composition, unit:10000 persons

Year	Population	By sex		By Agriculture and Non-Agriculture		Proportion of the total population(%)	
		Male	Female	Agriculture	Non-agriculture and Non-agriculture	Male	Non-agriculture
1949	1008.5	536.6	471.9	828.2	180.3	53.2	17.9
1950	1029.5	546.9	482.6	836.6	192.9	53.1	18.7
1960	1397.1	740.7	656.4	847.9	549.2	53.0	39.3
1970	1860.4	959.0	901.4	1305.3	555.1	51.5	29.8
1980	2210.7	1132.1	1078.6	1487.4	723.3	51.2	32.7
1990	2440.2	1248.1	1192.1	1488.3	951.9	51.1	39.0
1995	2550.9	1302.8	1248.1	1473.1	1077.8	51.1	42.3
2000	2627.3	1336.5	1290.8	1484.3	1143.0	50.9	43.5
2005	2669.4	1355.0	1314.4	1463.1	1206.3	50.8	45.2
2006	2679.5	1359.1	1320.4	1470.7	1208.8	50.7	45.1

Basic Statistics on Population of Jilin

	Unit	1999	2000	2001	2002	2003	2004	2005	2006
Total Households	Million	7.757	7.958	7.997	8.17	8.214	8.308	8.51	8.59
Average Population	Person/HH	3.43	3.32	3.34	3.3	3.27	3.24	3.16	3.14
Total Population	Million	26.576	26.817	26.908	26.994	27.037	27.085	27.16	27.23
Proportion of the total Population	%	48.41	49.66	49.8	50.88	51.77	52.3	52.52	52.97
Natural Growth Rate	‰	5.23	4.15	3.38	3.19	1.61	1.76	2.57	2.67

Gross Domestic Products, Calculated at the current prices, unit:100 million yuan

Year	Gross Domestic Product	Primary Industry	Secondary Industry			Tertiary Industry	Per Capita GDP (yuan)
				Industry	Construction		
1952	16.55	9.19	4.54	4.19	0.35	2.82	153
1960	41.83	8.26	24.64	22.17	2.47	8.93	289

1970	56.07	18.73	26.57	25.29	1.28	10.77	303
1980	98.59	27.24	52.24	47.42	4.82	19.11	445
1990	425.28	124.99	182.15	163.82	18.33	118.14	1746
1995	1137.23	303.99	475.22	413.85	61.37	358.02	4402
2000	1951.51	398.73	768.89	655.68	113.21	783.89	7351
2001	2120.35	409.10	852.51	724.73	127.78	858.74	7893
2002	2348.54	446.17	943.49	803.53	139.96	958.88	8714
2003	2662.08	488.15	1098.44	930.81	167.63	1075.49	9854
2004	3122.01	568.69	1329.68	1143.95	185.73	1223.64	11537
2005	3620.27	625.61	1580.83	1363.94	216.89	1413.83	13348
2006	4275.12	672.76	1915.29	1659.29	256.00	1687.07	15720

Output of Major Industrial Products above Designated Size[2]

Item	unit	2006
Coal	10000tonnes	2692.92
Crude Petroleum Oil	10000 tonnes	571.37
Natural Gas	100million cu.m	5.17
Electricity	100millionkwh	441.75
Thermal Power	100millionkwh	385.76
Hydropower	100millionkwh	53.15
Chemical Fiber	10000 tonnes	24.60
Yarn	10000 tonnes	6.86
Cloth	10000m	8228.6
Machine-made Paper and Paperboard	10000 tonnes	50.12
Crude Oil Processing	10000 tonnes	881.28
Gasoline	10000 tonnes	159.74
Diesel Oil	10000 tonnes	344.02
Caustic Soda	10000 tonnes	9.67
Synthetic Ammonia	10000 tonnes	51.04
Chemical Fertilizer	10000 tonnes	18.68
Chemical Pesticide	10000 tonnes	1.30
Ethylene	10000 tonnes	75.18
Cement	10000 tonnes	2524.98
Plain Glass	10000cu.m	769.60
Pig Iron	10000 tonnes	425.55
Crude steel	10000 tonnes	533.57
Steel	10000 tonnes	579.17
Aluminium Alloy	10000 tonnes	2.87

2 Industry with designated size means the output value is above 5million yuan.

Aluminum products	10000 tonnes	2.78
Industrial Boiler	tonnes	5162.48
Railway Passenger Coaches	coaches	1121
Motor Vehicles	10000 vehicles	63.25
Buses	10000 vehicles	5.77
Cars	10000 vehicles	40.70
Motorcycles	10000 vehicles	14.42
Household Refrigerators	10000 units	14.14

Overall Energy Balance Sheet (Standard Quantity), unit:10000 tonnes of SCE

	2005	2006
Total Energy Available of Consumption	5957.52	6622.36
Primary Energy Output	2791.53	3191.22
Recovery of Energy	341.91	165.33
Allocation from Outside	3951.27	3930.85
Import	46.59	15.05
Allocation from Inside	-1210.40	-564.49
Export	-28.85	-11.61
Stock at the Year End	-363.81	-528.21
Output and Input in Processing and Transformation	-34.09	-39.83
Thermal Power		
Heating		
Washing Coal	-9.19	-16.61
Coking	-9.17	-7.97
Petroleum Refining	-1.67	-2.11
Gas Production	-13.59	-13.06
Coal Products Processing	-0.47	-0.08
Losses	11.80	13.73
End-use Consumption	5911.74	6568.84
Primary Industry	196.03	210.32
Secondary Industry	4106.44	4606.07
Industry	4017.63	4505.82
Materials	378.72	447.70
Construction	88.81	100.26
Tertiary Industry	898.16	1006.18
Transport, Storage and Post	283.84	324.72
Wholesale, Retail Trade, Hotels and Catering Services	231.80	253.54
Others	382.52	427.92
Living Consumption	711.11	746.27

Urban	537.25	540.45
Rural	173.86	205.82
Balance	-0.11	-0.05
Total Consumption	5957.63	6622.41

AIM model sectors and key factors

Classification of energy end-use sectors and subsectors

Sector	Subsectors
Agriculture	Irrigation, farming works, agricultural-products processing, fishery, animal husbandry
Industry	Iron and steel, nonferrous metals, building materials, chemicals, petrochemicals, paper-making, textiles
Household	Urban and rural: Space heating, cooling, lighting, cooking and hot water, household electric appliance
Service	Space heating, cooling, lighting, cooking and hot water, electric appliance
Transportation	Passenger and freight: Railway, highway, waterway, airway Freight: Railway, highway, waterway, airway

Selected technologies considered in the IPAC-AIM/technology model

Classification	Technologies
Iron and steel	Coke ovens; sintering machines; blast, open hearth, basic oxygen, and AC and DC electric arc furnaces; ingot-casting machines; continuous-casting machines; continuous-casting machines with rolling machines; steel-rolling machines; continuous steel-rolling machines; dry and wet coke-quenching equipment; electric power generated with residue pressure on top of blast furnace; coke-oven gas, open- hearth gas, and basic oxygen-furnace gas recovery; cogeneration equipment
Nonferrous metal	Aluminum production with sintering process, aluminum production with combination process, aluminum with bayer, electrolytic aluminum with upper-insert cell, electrolytic aluminum with side-insert cell, crude copper production with flash furnace, crude copper production with electric furnace, blast furnaces, reverberator furnaces, lead smelting-sintering in blast furnace, lead smelting with closed blast furnace, zinc smelting with wet method, zinc smelting with vertical pot method
Building materials	Cement: Mechanized-shaft, ordinary-shaft, wet-process, lepol kiln, ling-dry, rotary with pro-heater, dry-process rotary with precalciner, Hoffman, and tunnel kilns; self-owned electric-power generators; electric power generators with residue heat; bricks and tiles Lime: Ordinary-shaft kilns, mechanized-shaft kilns Glass: Floating, vertical, and Colburn processes; smelters

Chemical industry	Synthetic ammonia: Converters, gasification furnaces, gas-making furnaces, synthetic columns; shifting of sulfur-removing equipment Caustic soda production: Electronic cells with graphite process, two-stage effects evaporators, multistage effects evaporators, rectification equipment, ion-membrane method Calcium carbine production: Limestone calciners, closed carbine furnaces, open carbine furnaces, residue heat– recovery equipment Soda ash: Ammonia and saltwater preparation, limestone calcining, distillation columns, filters Fertilizer: Equipment for production of organic products, residue heat utilization
Petrochemical industry	Atmospheric and vacuum distillation, rectification, catalyzing and cracking, cracking with hydrogen adding, delayed-coking, and light-carbon cracking facilities; sequential separators; naphtha, diesel, and de-propane crackers; de-ethane separators; crackers; facilities of residue heat utilization from ethylene
Paper-making	Cookers; distillation, washing, and bleaching facilities; evaporators, crushers; water-seperator, finishing, residue heat utilization, and black-liquor recovery facilities, co-generators; and back-pressure electric power and condensing electric power generators
Textile	Cotton-weaving process, chemical fiber process, wool-weaving and textile process, silk process, printing and dyeing process, garment-making, air conditioners, lighting, space heating
Machinery	Ingot process: Cupolas, electric arc furnaces, fans Forging process: Coal-fired, gas-fired, and oil-fired preheaters; steam- and electric-hydraulic hammers; pressing machines Heat-processing: coal-fired, oil-fired, gas-fired, and electric heat–processing furnaces Cutting process: Ordinary cutting, high-speed cutting
Irrigation	Diesel engines, electric induct motors
Farming works	Tractors, other agricultural machines
Agricultural products process	Diesel engines, electric induct motors, processing machines, coal-fired facilities
Fishery	Diesel engines, electric induct motors
Animal husbandry	Diesel engines, electric induct motors, other machines
Space heating in resident	Heat-supplying boilers in thermal power plants, district-heating plant boilers, dispersed boilers, small coal-fired stoves, electric heaters, brick beds linked with stoves (Chinese Kang), energy-saving building
Cooling in resident	Air conditioners, high-efficiency air conditioners, electric fans
Lighting in resident	Incandescent, fluorescent, and kerosene lamps

Cooking and Hot water in resident	Gas burners; bulk coal-fired, briquette-fired, methane-fired, cow dung–fired, kerosene, and firewood-fired stoves; electric cookers
Household electrical appliances	Televisions, washing machines, refrigerators, other appliances
Other electric equipment	Photocopiers, computers, elevator, other appliances
Space heating in service sector	Heat-supplying boilers in thermal power plants, boilers in district heating plants, dispersed boilers, electric heaters
Cooling	Central air conditioning, air conditioners, electric fans
Lighting	Incandescent, fluorescent lamps
Cooking and hot water	Gas ranges, electric cookers, hot-water pipelines, coal-fired stoves
Passenger and freight transport	Railways: Steam, internal combustion engine, and electric locomotives Highways: Public diesel, public gasoline, and private vehicles; large diesel freight trucks, large gasoline vehicles, small freight trucks Waterways: Ocean-going, coastal, and inland ships Aviation: Freight and passenger planes
Common technologies	Electric motors; frequency-adjustable electric motors; coal-fired, high-efficiency coal-fired, natural gas–fired, and oil-fired boilers
Power generation	Low-parameter coal-fired, high-pressure critical coal-fired, super-critical coal-fired, natural gas–fired, oil-fired, and nuclear generators; PFBC, Integrated gasification combined cycle, Natural gas combined cycle; wind turbines; hydropower; solar power generation; biomass and landfill power generation

Source: Jiang et al, 1998

Factors influenced by key driving forces

Driving force	Sector	Factors	Policies to promote the change
Social-efficiency change	Industry	Value-added change by subsectors within the sector (as service demand of some subsectors, including machinery, other chemical, other mining, and other industry, could be changed based on economic mix change) Products structure change within one sector (as service demand in most industrial sectors)	Various policies relative to value added, such as price policy, national plan for key industry, promotion of well-functioning markets, market-oriented policies, national development policies
	Residential and commercial	Change in energy activity within the sector (use of heating, cooling, more efficient electric appliances)	Public education, price policies
	Transport	Change of transport mode (more public transport, nonmobilty(walking and bicycle use) traffic volume (as result of decline in use of private cars)	Transport development policies, public education
Technology progress	All sectors	Efficiency progress for technology (improvement in unit energy use); changes in technology mix (more advanced technologies); changes in fuel mix (more renewable energy and nuclear)	Promotion of technology R&D, market-oriented policies, international collaboration, environmental regulation, energy-industry policies, import and export policies, tax system

Source: Jiang at al, 2006

Model parameters and assumptions

Parameters for urban household

		2005	2006	2010	2020	2030
HH		4626267	4839935	5239181	6050837	6981349
member per HH	Person	3.0	3.0	2.8	2.7	3.1
Index: 2005=1						
Cooking		1	1.1	1.1	1.2	1
Electric cooking		1	1.4	1.1	1.3	1
Hot water		1	2.4	1.1	2.0	1
Space heating		1	1.1	1.1	1.2	1
Air Conditioner		1	3.2	1.1	4.9	1
Fan		1	1.4	1.1	1.7	1
Lighting: Incandescent		1	1.1	1.1	1.2	1
Lighting: Fluorescence		1	2.0	1.1	1.2	1
Refrigerator		1	1.4	1.1	1.4	1
Colour TV		1	1.9	1.1	1.4	1
Washing Machine		1	1.5	1.1	1.6	1
Other electric appliance		1	1.1	1.1	1.2	1

Parameters for rural household

		2005	2010	2020	2030
Population		12672412	12131086	10891506	9350776
HH	HH	3200104	3369746	3300456	3016379
member per HH		4.0	3.6	3.3	3.1
Index, 2005=1					
Cooking		1	1.2	1.2	1.2
Electric cooking		1	1.0	2.0	2.8
Hot water		1	31.1	60.2	62.8
Space heating		1	1.2	1.2	1.2
Air Conditioner		1	9.0	41.3	172.8
Fan		1	2.8	5.6	7.7
Lighting: Incandescent		1	1.0	0.9	0.8
Lighting: Fluorescence		1	1.4	1.8	2.1
Refrigerator		1	2.2	4.9	5.3
Colour TV		1	1.3	1.9	2.1

Black/White TV		1	0.0	0.0	0.0
Cloth Washing		1	1.5	1.9	2.3
Other electric appliance		1	1.7	2.3	2.7

Key assumptions for service sector

		2005	2010	2020	2030
Area	1000m2	190000	266484.8	434075.706	583361.45
Index, 2005=1					
Cooling		1.0	1.9	4.1	8.1
Space Heating		1.0	1.7	3.4	5.8
Lighting		1.0	1.6	3.3	5.5
duplicating machine		1.0	1.7	3.6	6.0
Computer		1.0	1.8	3.8	6.7
Elevator		1.0	1.7	3.3	5.4
other electric appliance		1.0	1.7	3.6	6.3
Hotwater		1.0	1.6	3.3	5.3
Cooking		1.0	1.7	3.6	6.1

Vehicle number in Jilin, 1000

	2005	**2010**	**2020**	**2030**
Total Vehicle	759	1201	3851	7086
Passenger	465	973	3512	6585
Freight	179	228	338	501
Car	265	593	3002	5885
Family Car	186	487	2794	5546
Other Car	79	106	208	339
Mini-Bus	123	220	286	378
Large Bus	77	160	224	322
Bus	200	380	510	700
Motor Cycle	1336	1404	1551	1713
Bicycle	8200	8661	9567	10568

Technologies that save energy and reduce greenhouse gas emissions in the short and medium term

Sector	Technologies
Steel	Large-size equipment (coke ovens, blast furnaces, basic oxygen furnaces); coke dry-quenching equipment (CDQ); continuous casting machines; Blast-furnace gas recovery; continuous rolling machines; coke-oven gas equipment; open hearth gas and blast furnace gas recovery; DC electric arc furnaces
Chemicals	Large-size equipment for chemical production, waste-heat recover

	systems, ion membrane technology, improvements in existing technology
Paper-making	Cogeneration systems, residue-heat utilization facilities, black- liquor recovery systems, continuous distillation systems
Textiles	Cogeneration systems, shuttleless looms, high-speed printing and dyeing
Nonferrous metal	Reverberator furnaces, waste-heat recover systems, New furnace for lead and zinc production
Building materials	Dry-process rotary kilns with precalciners, electric power generators with residue heat, Colburn process, Hoffman and tunnel kilns
Machinery	High-speed cutting, electric-hydraulic hammers, heat-preservation furnaces
Residential	Cooking by gas, centralized space heating system, energy-saving electric appliances, more efficient lighting, solar thermal for heating water, insulation of buildings, energy-efficient windows
Service	Centralized space-heating systems, centralized cooling systems, cogeneration systems, energy-saving electrical appliances, high-efficiency lighting
Transport	Hybrid vehicles, advanced diesel trucks, low energy-use cars, electric cars, fuel-cell vehicles, natural-gas cars, electric railway locomotives, public transport development
Common use technology	High-efficiency boiler, fluid-bed combustion technology, high- efficiency electric motors, speed-adjustable motors, centrifugal electric fans, energy-saving lighting
Power generation	Supercritical units, natural-gas combined cycles, pressured fluid- bed combustion boilers, wind turbines, integrated gasification combined cycles, smaller-scale hydropower, biomass-based power generation

Detailed outputs from the Jilin Scenario

Energy use by sectors, BaU scenario, Mtce

2006	Coal	Oil	N.Gas	Heat	Electricity	Total
Agriculture	0.5	1.1	0.0	0.0	0.1	1.9
Industry	20.6	6.9	0.6	3.7	3.6	36.2
Tertiary	4.1	1.1	0.0	0.3	0.6	8.7
Transport	0.9	4.5	0.0	0.1	0.2	2.9
Urban	1.3	0.6	0.1	1.1	0.5	4.1
Rural	0.6	0.1	0.0	0.0	0.3	1.4
Total	**27.2**	**14.3**	**0.7**	**5.1**	**5.1**	**52.3**
2010	**Coal**	**Oil**	**N.Gas**	**Heat**	**Electricity**	**Total**
Agriculture	1.0	2.1	0.0	0.0	0.2	3.2
Industry	37.8	13.9	1.3	5.8	6.9	65.8

Tertiary	7.0	1.6	0.1	0.5	1.4	10.5
Transport	1.3	6.1	0.0	0.1	0.2	7.8
Urban	2.0	1.1	0.2	1.7	0.9	5.9
Rural	1.3	0.2	0.0	0.0	0.4	1.9
Total	**49.0**	**25.0**	**1.5**	**8.1**	**9.9**	**87.4**
2020	**Coal**	**Oil**	**N.Gas**	**Heat**	**Electricity**	**Total**
Agriculture	1.2	2.7	0.0	0.0	0.3	4.2
Industry	44.9	19.5	3.0	8.2	13.6	89.2
Tertiary	9.7	2.1	0.1	0.8	2.8	15.5
Transport	1.5	8.5	0.0	0.2	0.4	10.5
Urban	2.1	1.5	0.3	2.3	1.8	8.1
Rural	2.1	0.3	0.0	0.0	0.9	3.3
Total	**60.0**	**34.7**	**3.4**	**11.3**	**19.4**	**128.8**
2030	**Coal**	**Oil**	**N.Gas**	**Heat**	**Electricity**	**Total**
Agriculture	1.2	3.5	0.0	0.0	0.5	5.3
Industry	41.3	25.6	4.3	10.6	23.0	104.9
Tertiary	9.0	2.7	0.1	1.1	5.6	18.5
Transport	1.3	11.9	0.0	0.2	0.6	14.0
Urban	1.7	2.1	0.4	3.0	3.3	10.6
Rural	2.0	0.5	0.0	0.0	1.5	4.1
Total	**55.2**	**46.4**	**4.8**	**14.8**	**33.9**	**155.2**

Energy use by sectors, policy scenario, Mtce

2006	Coal	Oil	N.Gas	Heat	Electricity	Total
Agriculture	0.5	1.1	0	0	0.1	1.9
Industry	20.6	6.9	0.6	3.7	3.6	36.2
Tertiary	4.1	1.1	0	0.3	0.6	8.7
Transport	0.9	4.5	0	0.1	0.2	2.9
Urban	1.3	0.6	0.1	1.1	0.5	4.1
Rural	0.6	0.1	0	0	0.3	1.4
Total	**27.2**	**14.3**	**0.7**	**5.1**	**5.1**	**52.3**
2010	**Coal**	**Oil**	**N.Gas**	**Heat**	**Electricity**	**Total**
Agriculture	0.8	1.8	0	0	0.2	2.8
Industry	33.8	11.7	1.3	5.8	7.1	59.8
Tertiary	5.8	1.5	0.1	0.5	1.4	9.3
Transport	1.2	5.6	0	0.1	0.3	7.2
Urban	1.9	0.8	0.2	1.7	1	5.6
Rural	1.1	0.2	0	0	0.4	1.7
Total	**43.5**	**21.6**	**1.5**	**8.1**	**10.1**	**79.2**
2020	**Coal**	**Oil**	**N.Gas**	**Heat**	**Electricity**	**Total**
Agriculture	1	2	0	0	0.3	3.3
Industry	37.6	13.5	2.4	7.1	12.1	72.6

Tertiary	7.6	1.7	0.1	0.7	2.6	12.7
Transport	1.2	7.4	0	0.2	0.4	9.2
Urban	1.8	0.9	0.3	2	1.7	6.7
Rural	1.5	0.3	0	0	0.8	2.7
Total	**49.5**	**25.9**	**2.7**	**9.8**	**17.6**	**105.4**
2030	**Coal**	**Oil**	**N.Gas**	**Heat**	**Electricity**	**Total**
Agriculture	1	2.5	0	0	0.4	3.9
Indhustry	32.3	16.5	3.1	8.8	16.2	76.9
Tertiary	6.5	2.2	0.1	1	4.5	14.3
Transport	1	9.6	0	0.2	0.7	11.5
Urban	1.3	1.3	0.4	2.6	2.8	8.4
Rural	1.5	0.6	0	0	1.3	3.4
Total	**42.6**	**32.6**	**3.6**	**12.5**	**25.2**	**116.4**