

Title: China's Long Term Energy Demand Forecast——An application of a hybrid model of CGE and energy demand modules

Authors: Jifeng LI, Yaxiong ZHANG (SIC)

Abstract: State Information Center (SIC) started to develop a hybrid model of CGE and energy demand modules from 2014. To build the model, three principles are adopted: the forecast of final energy demand depends on macroeconomic development and industrial change; The primary energy demands are reversely calculated by final energy demand; The primary energy supply will meet the demand. Based on the hybrid model, we carried out the scenario studies on China's long term energy demand estimation. The basic conclusions include:

1) Following that the economic development will change to a new pattern, the energy demand growth will be much slower relative to the last decade; 2) total energy consumption will be about 5000 Mtce at 2020 and 6000 Mtce at the reference scenario, the coal consumption has entered a stable period, kept at 4200 Mt to 2030, and share on total primary energy will be reduced to lower than 60% at 2020 and 50% at 2030; 3) If the supply-side reformation was accelerated, the total primary energy demand will be reduced to 4800 at 2020.

1 Introduction

China and US jointly issued the historic and landmark "Sino-US Joint Statement on Climate Change" in November 12, 2014, China intends to achieve the peaking of CO₂ emissions around 2030 and to make best efforts to peak early and intends to increase the share of non-fossil fuels in primary energy consumption to around 20% by 2030.

China economy has been suffering a painful period since 2012. The traditional driving force coming from the continuous development of property is changing weak, but the new ones are not been well developed. There is no doubt about the slow-down of economic growth in the next decade and the low growth of the energy consumption to meet the CO₂ emission peaking target before 2030, but we need to give out a quantitative results to show the reasonable pathway.

In the study, we developed a hybrid economic and energy model to study the energy demand till 2030. The hybrid model was built based on our dynamic CGE model and four energy modules, and the energy demand forecast was began from the economic forecast.

In the study, for each scenario, we will get a set of consistent results including macroeconomic growth rate, industrial structure, final energy demand and primary energy demand.

2. The model

2.1 The Framework of model

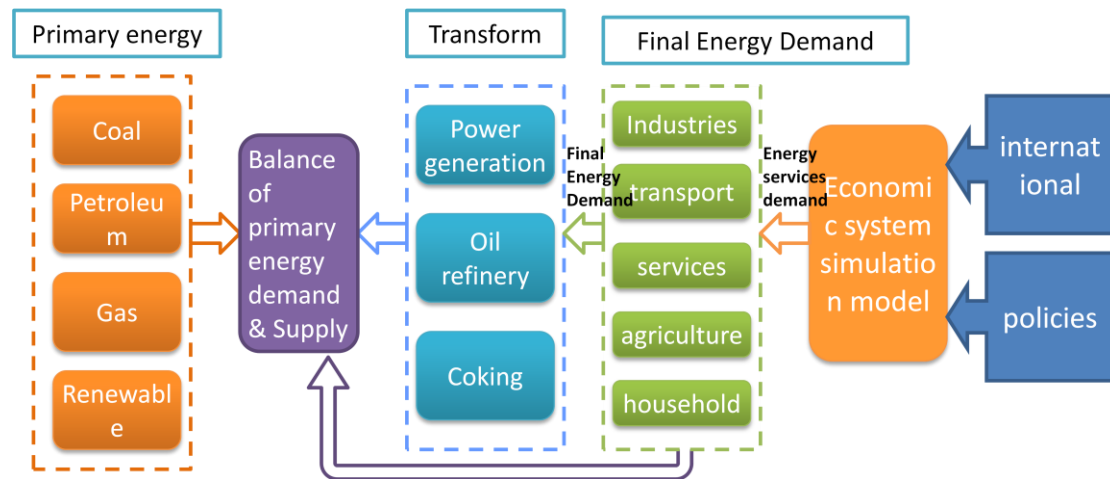


Fig. 1 The framework of hybrid economy-energy demand model

The model is not a typical hybrid model linking bottom-up model, like TIMES or Message, and top-down model, like pure CGE or econometric model. The model is more like the extension of an CGE model to the energy sectors. The framework of the model is shown in Fig.1:

Firstly, with the qualitative assumption of international economic environment and important policy, an econometric macroeconomic model was built to assess the growth potential of GDP until 2030.

Then a CGE model, which was named as SICGE, was adopted to carry out the industrial development by keeping consistent with the total GDP, and coupling the industrial mix and demand structure.

Thirdly, by given the output of all industries and household consumption, we developed five energy modules, including electricity, coal, oil, gas demand module and a power generation modules to calculate the corresponding energy demand.

Finally, by given the demand of primary energy, the supply structures are

estimated.

2.2 General introduction of SICGE

The SIC-GE model is a dynamic computable general equilibrium model used as an auxiliary tool by the Chinese government for public policy decisions.¹ Some precisions of its key features are given below in order to ensure a better understanding of the research results of this paper.

The current database includes 175 commodities and 162 sectors, assembled from China's 2007 Input-Output Table and updated by observed data annually. This ensures the model accuracy when analyzing policies of recent years (for example, the year 2007 which is the reference year of this paper). The sectors and commodities are composed of two parts: First, the original 2007 input-output table of China contains 135 sectors where only one agriculture and 6 energy sectors are included. Secondly, we further disaggregated the agricultural sector and energy into more subsectors. Except the agricultural sector, we spit the 6 energy producing sector into 13 sector and 21 products. The classification of product covers the energies used in the 5 energy modules.

¹ It was co-developed by the State Information Center (SIC) of China and the Monash University of Australia.

Initial sectors	Initial products		Sectors in SICGE	Products in SICGE
Coal mining	coal	→	Coal mining	coal
Oil&gas extraction	Crude oil and gas product	→	Oil&gas extraction	Crude oil, natural gas
Oil refinery	Refinery products	→	Oil refinery	Gasoline, diesel, kerosene, fuel oil, light oil, LPG, oth
coking	coke	→	coking	Coke, coking gas
electricity & heat production	Electricity & heat	→	Coke based chemical	Coke based chemical products
Gas production	Fuel gas	→	Power Grid	Transmission and distribution service of power
		→	Coal-fired power	Coal-fired power
		→	Hydro power	Hydro power
		→	Nuclear power	Nuclear power
		→	Wind power	Wind power
		→	Solar power	Solar power
		→	Gas-fired power	Gas-fired power
		→	Gas production	Fuel gas

SIC-GE distinguishes five labour types² given the segmentation of China's labour markets, thus enabling the analysis to take employment impacts into consideration.

The core and dynamic (recursive) modules of SIC-GE are based respectively on the ORANI model (Dixon et al., 1982) and the Monash model (Dixon and Rimmer, 2002). SIC-GE includes six core modules which are the production module, investment module, household and government consumption module, export module, price and tax module, and dynamic module. For the first five modules, the theory basis is

² Rural agricultural worker, rural non agricultural worker, rural-urban migration worker, urban skilled worker and urban un-skilled worker.

similar to most of the CGE models. For instance, in the production module, the multi-level nested production function was applied to describe the production process in each industry. The cost minimization is used to illustrate the demand of primary inputs and intermediate inputs. For the dynamic module, there are two main equations. One describes the capital accumulations (including new investments); the other describes the net foreign liability accumulations (including the foreign liability and foreign assets).

2.3 energy modules

2.3.1 Electricity demand forecast module

The total electricity consumption was estimated by separated into some subsectors, shown as fig.2.

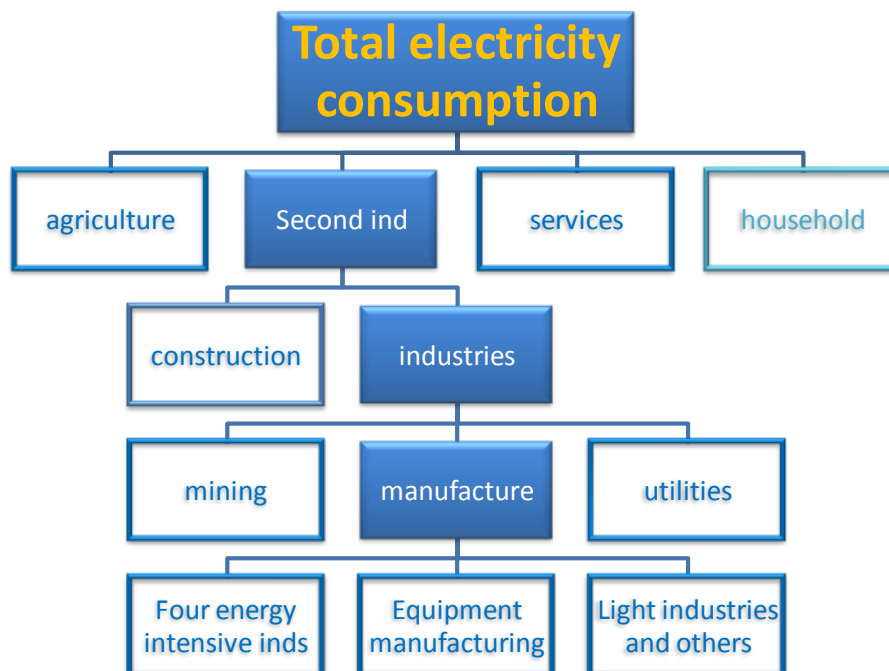


Fig.2 the electricity consumption estimation module

For agriculture, services, light industries and equipment manufacturing industries, their electricity consumption are estimated according to the growth of value added which is provided by SICGE. And particularly, we give more efforts on energy intensive industries.

In 2015, the four energy intensive sectors, including iron, nonferrous metal, non-metallic mineral product and basic chemical producing, consumed more than 30% of total electricity. Till 2030, following the industrialization and urbanization process, the development trend of these sectors will heavily impact on the total electricity consumption. In the study, we link the electricity consumption of these four sectors with more detailed products productions. For instance, the production of crude steel and pig iron in iron&steel sector, the aluminum in non-ferrous metal sector, the ethene, synthesis ammonia, caustic soda, calcium carbide in chemical sector, and the cement and glass in building material sector. All of these products production are estimated based on the engineering experiences. It should be noted that the value added growth of these four sectors in SICGE are also exogenous and calibrated follow the trend of these products.

2.3.2 Coal consumption forecast module

In China, more than 80% of coal was used in the power generation, iron&steel production, cement production and chemical production, the left 20% are utilized dispersedly, including in light industries, household

and services, etc. Similarly with electricity module, we estimate the coal consumption based on the forecast of the main product quantity.

2.3.3 Oil consumption forecast module

In the module, we estimate the gasoline, diesel, kerosene, light oil, LPG and other petroleum product separately. Gasoline and part of diesel demand are estimated according to the vehicle population estimation. The left part diesel consumed in industry is linked to the fixed capital investment. More than 90% of kerosene was used in air flight; we link the kerosene consumption with the total turnover volume of air flight, including the flight of passenger and goods. Light oil consumption is linked to the main crude chemical products; and LPG is partly linked to the urbanization of population and partly linked to ethene product.

2.3.4 Natural gas consumption forecast module

More than 70% natural gas was consumed as the fuel combustion in manufacturing, household consumption and transport. The gas-fired power generation was less developed till now, and it is also limited to be used as the material of chemical production. In the study, we estimate the consumption in household by a relative stable growth rate according to the urbanization process. The consumption in transportation sector mainly depends on the substitution to gasoline and diesel. And the consumption in power generation was decided by the potential of substitution of dispersed utilization of coal in most of light

manufacturing sectors, and the room of power generation for peaking load. There is large potential to increase for natural gas used as fuel in glass, china, ceramic tiles and chemical products, etc., however it mostly depends on the natural gas price relative to the alternative fuel price.

2.3.5 Feedbacks from energy modules to SICGE

Although most of energy was estimated based on the sectoral value added provided by SICGE model, it should be noted that there are also some feedbacks to SICGE model to ensure them consistent in the reference scenario.

There are two kinds of variables was feedback to SICGE. One is the main industrial product quantities which are estimated by the engineer. These results will be used to calibrate the related industries development; the other is the output of energy demand.

3. Scenario design

In this study, we have built a reference scenario and one policy scenario to reflect the impact of supply side reformation on energy consumption.

The reference scenario is carefully built to absorb the information from economist, government officials, engineers in energy sectors and downstream sectors as much as we can.

One policy scenario was designed to reflect part of the supply-side reformation based on the reference scenario. There will be a lot factors

to affect the economic growth rate and pattern, also the energy consumption pattern in the future. Based on such a model system, we are carrying out the policy scenarios. In the next five year, one of the most important policies in China will be the supply-side reformation, which is a systematic reformation and would introduce obvious change of energy consumption pattern through changing the industrial mix. In the paper, we didn't try to cover all factors, but to estimate the impact to reduce the oversupply of energy intensive product and increase the abundance of consumption commodities to raise the consumption ratio in final demand. In the reference scenario, the consumption ratio in 2020 is set as 52% (2010 constant price), and 54% (2010 constant price) in 2030. In the policy scenario, the consumption ratio in 2020 will be go up to 53.5%, the consumption ratio in 2030 should be calculated by the model.

4. Results in reference scenario

4.1 Macroeconomic development

China's economy has shifted to a new development phase. On the demand side, the growth of investment and export has significantly weakened, while the growth of consumption has stabilized. On the supply side, the manufacturing sector is facing severe overcapacity after rapid expansion. While the productivity of service sector is relatively lower, causing the overall decline in the economic efficiency. Along with the changes in the structure of the population, the working population is

reduced, dependency ratio of population increases, the savings rate and investment rate tend to decline, and labour input and capital investment slow down. The economic growth depends more on efficiency improvement rather than massive capacity expansion.

China's industry will continue to slow down but maintain a modest growth rate during the 13th Five Year Plan period and the next decade. There is still large potential for capital investment, such as in the public service sector, infrastructure in the less developed western region, and in real estate, and to support the advance industry development, there also need a large scale investment in new emergent manufacture industries, like general equipments, cars, electric equipments, computer and communication equipments, which are shown in fig3.

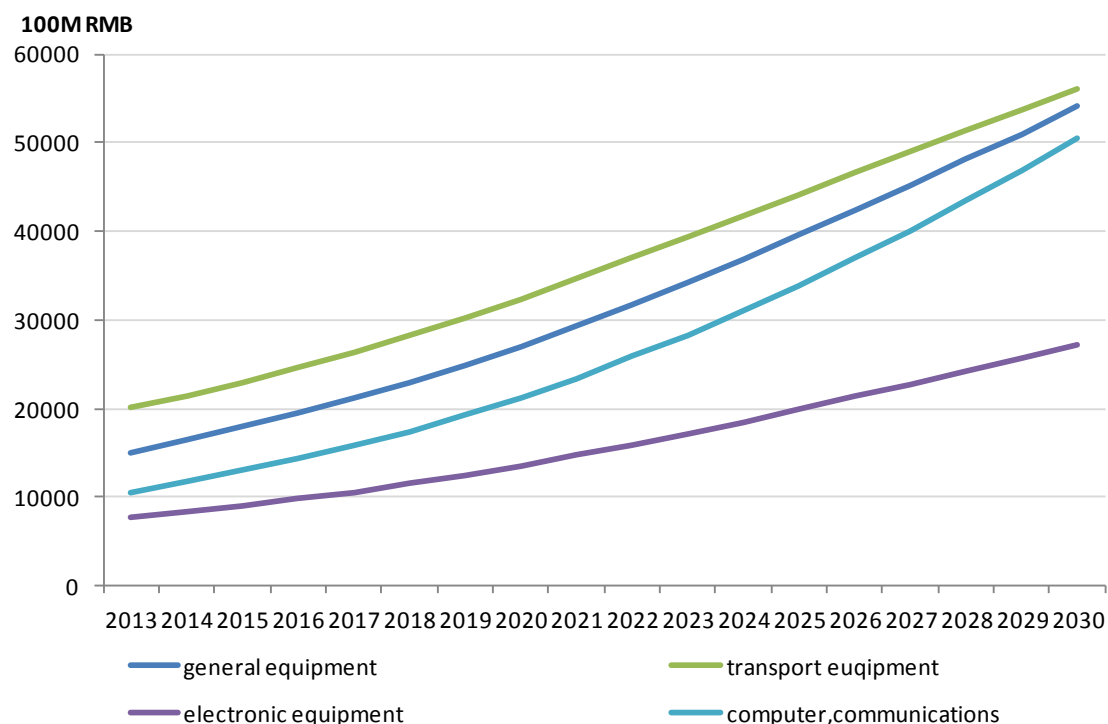


Fig.3 the equipment industries growth trend till 2030

Not like that the energy intensive industries were peak already or soon, which will be analyzed in the next segment, the services industry development mainly depends on the private consumption and government consumption increase, which will increase steadily, shown in Fig.4.

Based on the above analysis, we estimated the GDP growth rates for the period of 2016-2020, 2021-2025 and 2026-2030 are 6.7%, 6.2% and 5.4% respectively.

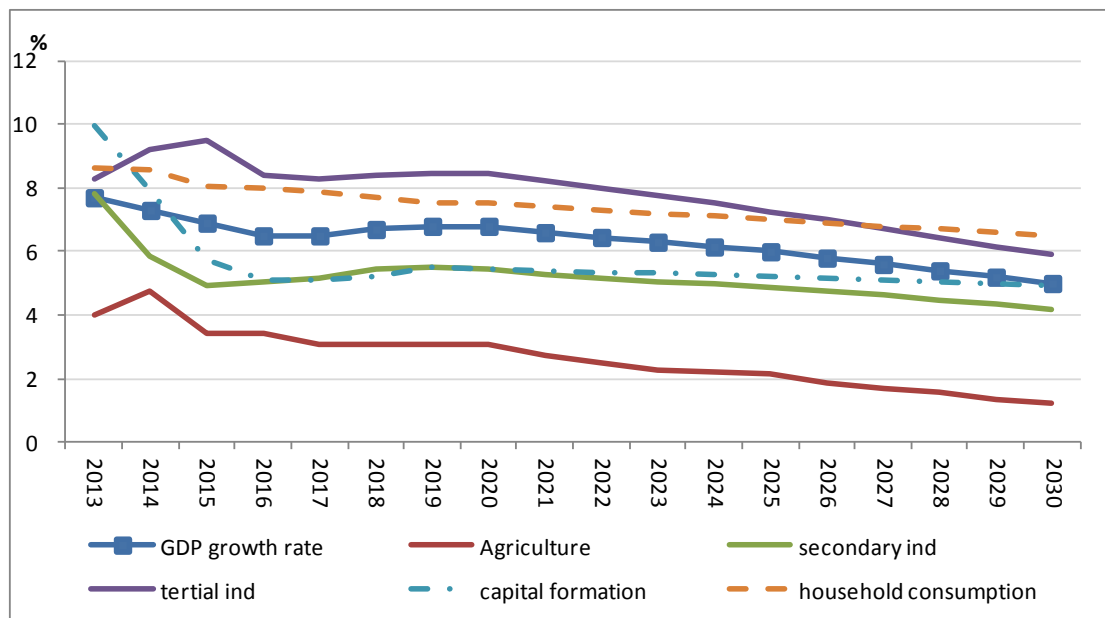


Fig. 4 GDP, main sector and main demand growth

4.2 Major energy-intensive sectors

In the study we analyzed some main energy intensive sectors, like real estate, steel, cement and non ferrous metal, transport and other sectors. Here we give out our estimation on steel, cement and non ferrous metal, show in Fig.3.

4.2.1 Iron and steel

China's economy gradually slows down since the global financial crisis in 2008. The demand for steel experienced negative growth for the first time in 2014, affected by the slowdown in real estate investment, overcapacity of industry. Considering the extension of real estate build has finished, and the annual production of house will reduce gradually, the demand for steel would be smaller year on year.

Based on the forecast, The peak time of crude steel consumption has gone, the consumption of iron and steel in the baseline scenario will be: 800 million tons in 2015, 720 million tons in 2020, and 590 million tons in 2030.

4.2.2 Building materials

The building sector is as important as the steel to the national economy during the extension of fix capital investment in the past decades. The building materials mainly covered non-metallic mineral products, new inorganic non-metallic materials and other related industries. The traditional building materials industry includes cement, plate glass, building sanitary ceramics, wall materials and lime and others, which are energy intensive furnace industry furnace. Driven by the rapid development of the national economy, the building sector maintains a rapid growth.

At present, China's building materials industry technology and equipment level close to or reach the world advanced level. The industry has comprehensive knowledge of drykiln technology, large float glass, large glass fiber wiredrawing and other advanced production technology, and has the ability to manufacture a complete sets of equipment.

At the same time, the industry is facing severe overcapacity. In 2012, cement production capacity was almost 3billion tons, excess capacity rate is 35.7%. Flat glass production capacity was 9.24 weight cases, excess

capacity rate is 29.4%. Overcapacity and intense competition result in price fluctuations and insufficient operation rate. The profits of many enterprises fell down. In 2012, the profits of cement factories went down from 15% to 50% across the country.

By analysing the relationship between China's consumption of cement and iron and steel during the 1978 -2013, it is found that the two has good correlation and high consistency. Since 2005, the steel consumption coefficient per GDP and the cement consumption coefficient per GDP have decreased year by year, both of which declined in 2008 affected by the financial crisis, and rebounded a little in 2009 by the domestic large-scale economic stimulus.

However it should be noted that the substitution by aluminium partly decrease the steel consumption and make it peaked at 2014, the cement consumption won't decrease totally following the trend of steel consumption. We assume the cement will be stabilised until about 2020, and then decreased gradually, following the trend of real estate consutruction.

4.2.3 Non-ferrous

According to the "11th Five Year" plan, the demand for non-ferrous metals from the power generation, power grid, transportation equipment (car, train, subway, etc.), electronic machinery manufacturing, aerospace, construction, equipment manufacturing and other industries will continue to grow. Non-ferrous metals as basic raw materials will be strategic for the in-depth development of industrialization and industrial upgrading. It is expected that this sector will maintain a growth rate of about 3% before 2030.

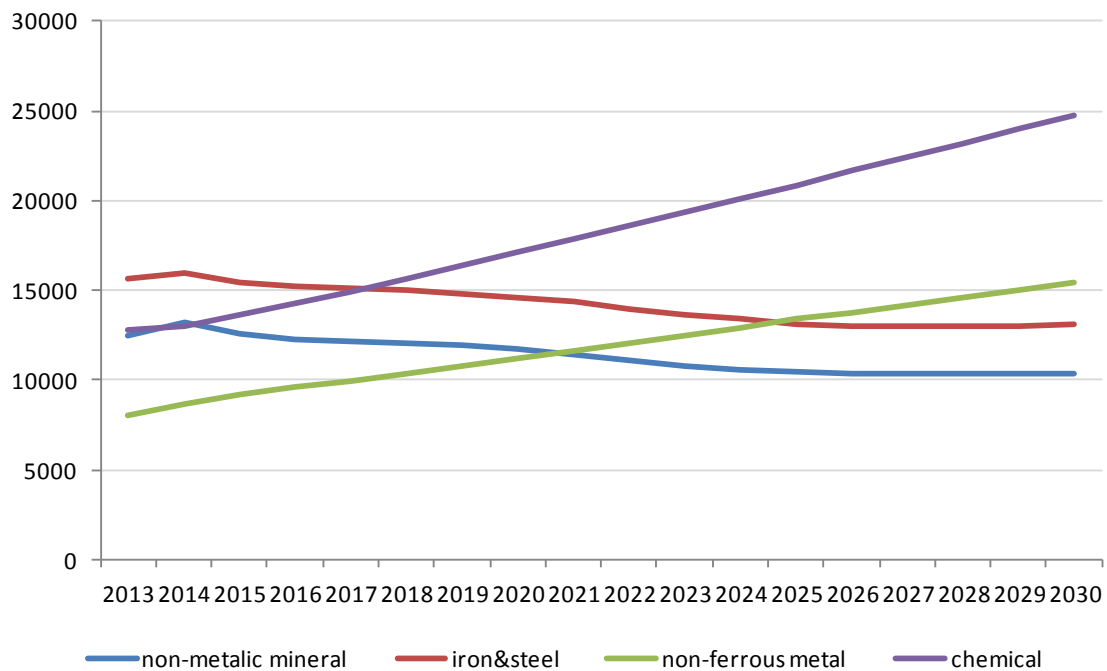


Fig. 5 Main energy intensive industries development till 2030

4.3 Energy consumption

Based on the comprehensive analysis of China's economic and social development, and the estimate of the peak of major energy-intensive industries, we estimate China's future energy consumption till 2030.

4.3.1 Total primary energy demand

China's total primary energy consumption will continue to rise, but not as fast as before, showing early sign of slow "decoupling" between the energy consumption and economic growth. It is estimated that the energy consumption will reach at 4.3billion tons of standard coal (tce) in 2015, 5.0 billion tce in 2020, and 6.0 billion tce in 2030. The average annual growth rate will drop from 2.8% from 2016-2020 to 2% from 2021-2030 (Table 1)

Table 1: 2013-2030 Economic development and energy consumption forecast

	2015	2020	2025	2030
GDP annual growth rate (%)	6.9	6.7	6.2	5.4
Energy consumption (100Mtce)	43.0	49.5	55.7	60.2
Energy consumption annual growth rate (%)	1.0	2.8	2.4	1.5
Energy consumption elasticity	0.14	0.42	0.39	0.28

4.3.2 energy mix

According to the characteristics of China's energy resource endowment, as well as international energy development and utilization of market potential, considering the domestic industrial structure adjustment and optimization of environmental carrying capacity constraints, the future of China's energy development will be focused on the development of clean energy and clean coal, and continued optimization of the energy structure. By 2030, coal, oil, natural gas will account for 48%, 16%, 15% of the energy consumption respectively. While in the case of further development of hydro, nuclear, wind power, solar and biomass power generation, the proportion of non-fossil energy sources is expected to increase to 21% by 2030.

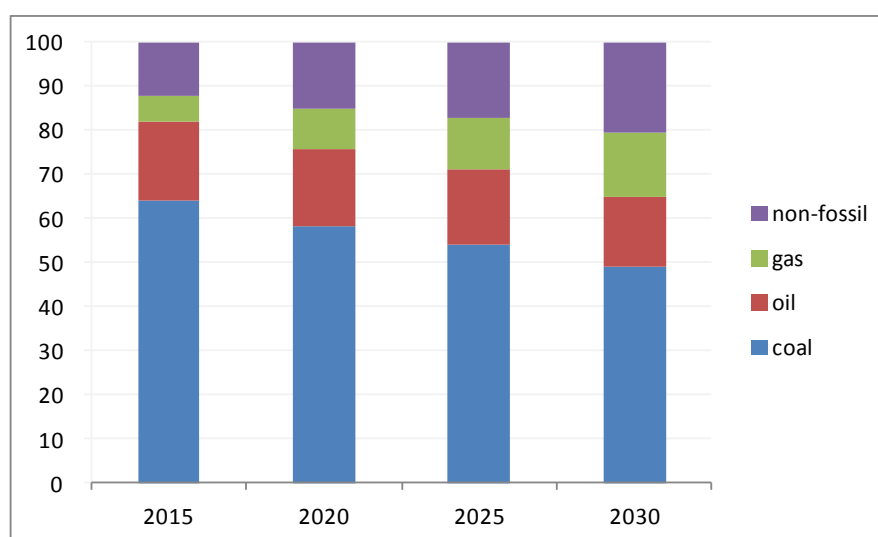


Figure 6 Energy demand structure

We also estimate the electricity consumption and the power generation. following the industrial growth, the electricity consumption are estimate, the total electricity consumption will be 7.2 trillion kwh at 2020, and 10.6trillion kwh at 2030. Considering the increase of electricity consumption, the contribution of the increase in secondary industry will be 56% from 2016-2020, and reduce to 38% from 2021-2030; on the contrary, the contribution of service industry and household will be 19% and 25% in 2016-2020, and increase to28% and 33% in 2021-2030. Such results follow the diverse trend of different industries development.

In terms of power generation, which is complicated issues in China with a lot of uncertainties. Here we only give out a relatively practical path way, shown in Fig8. The coal fired generation is still the main source, but the share will reduce from 68% at 2015 to 60% at 2030; share of nuclear increase from 3% to 9.5%, and wind and solar increase from 4% to 9.8%,showing a fast growth period for renewable energy.

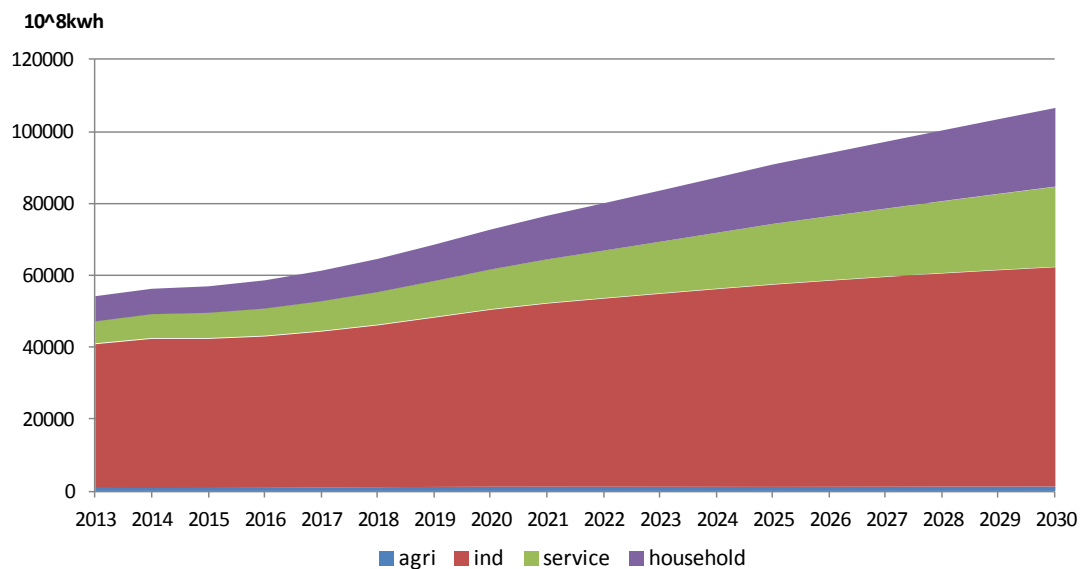


Fig.7 the electricity demand development till 2030

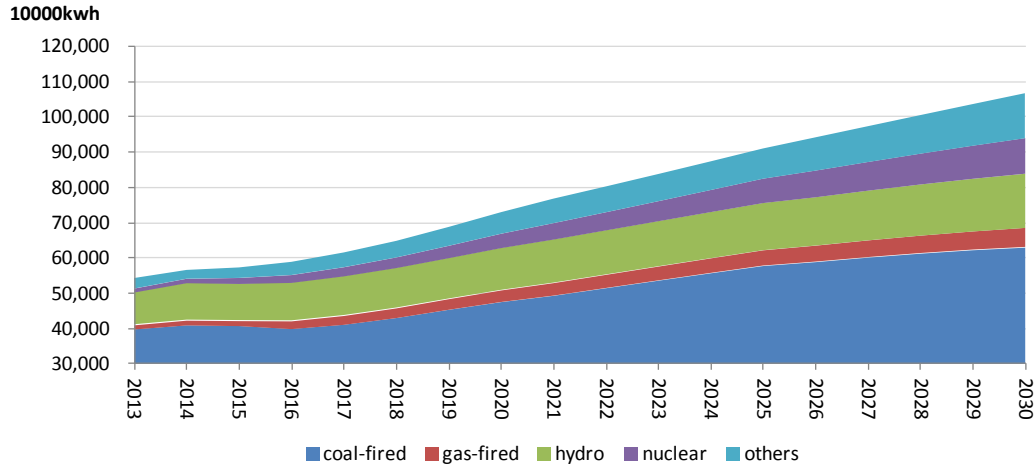


Fig.8 the power generation mix till 2030

5. Results change in policy scenario

In the policy scenario, the consumption was increased by increasing the average consumption propensity to increase the consumption ratio from 52% to 53.5% in 2020. Through the equilibrium calculation by SICGE, the structure change can be shown as follows:

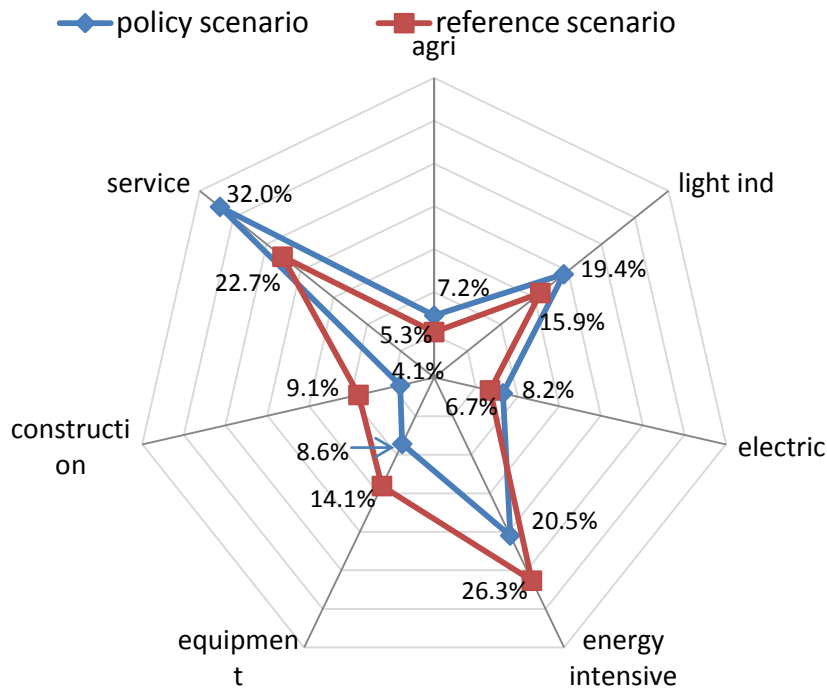


Fig.9 the industrial mix change at 2020

In the reference scenario, from 2016 to 2020, the total increase of value

added are distributed to all sectors like the red line in Fig.9, but in the policy scenario, the distribution will be like the blue line in Fig.9. We assume the total GDP increase doesn't change much by through reducing the tax, but not shown here. Such industrial mix change has an obvious impact on energy demand, shown in table 2. The total primary energy would be reduced to 4800 mtce in 2020, 150 mtce would be saved. The total consumption of coal would reduce to 4000 Mt at 2020, which meant in the policy scenario, the reduction of coal would contribute 90% of reduction of total energy consumption in 2020.

Tab.2 Total energy demand comparison between scenario in 2020 (100M tce)

		total	agri	Light inds	Electric inds	Energy intensive inds	Equipment inds	construction	service	household
2015		43.0	0.8	3.3	0.6	23.4	1.8	0.7	7.3	5.1
2020	reference	49.6	1.0	3.9	0.7	25.9	2.2	1.1	8.1	6.6
	policy	48.1	1.1	3.9	0.7	24.5	2.0	0.9	8.4	6.6

6. conclusions

In the next five years, keeping a medium growth rate of economic development is still critical important. By given the 2020 economic development target, the energy demand could be in the range of 4800-5000 mtce at 2020. The energy mix will changes to more clean, in which, the share of coal will reduce to under 60%, and the share of non-fossil fuel will rise to more than 15%. The increase from traditional energy intensive industries will reduce, but the energy demand in new advanced emerging industries, household and services will keep increasing. To implement the supply side reformation will help to reduce the energy demand, and mainly reduce the coal consumption.

After 2020, it is still essential to keep the economic growth at a medium speed to pass the “middle income trap”, the energy demand will keep growing, and arrive at 6000 mtce at 2030. To meet the peaking target of CO₂ emission, the consumption of coal can not increased, which share will reduce to lower than 50%, and the natural gas will grow fast at the decade, which share will go up to 15%, close to the share of oil; and the share of non-fossil fuel will also be bigger than the target, 20%.