How does the power industry support the national economic and social sustainable development?

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Abstract: In recent years, the power industry experienced rapid development in China. The report introduces the active efforts and contributions made by the Chinese power industry to the national economic and social sustainable development from multiple aspects with data including the technical indicators such as net coal consumption rate, auxiliary power ratio, line loss rate, etc. as well as the development or increase of cleanly energy generators, desulfurization equipments, cross-regional electric energy transmission and Energy Service Companies (ESCo).

With the higher influence of the developing concepts such as the low carbon and environmental-friendly in the social development, Chinese economy would realize the sustainable and great-leap-forward new industrialization in future. Take the capacity of the units, the level of technology, and the desulfurization in 2005 as references, the accumulated primary energy saved was 298 million tce, the alternative fossil fuels saved were 290 million tce, and the SO_2 emission reduced was 9.7 million ton during the "Eleventh Five-Year Plan" period (2006-2010).

The power industry will still play the main role of contributor to the national economic and social sustainable development in the future. In 2020, the proportion of the installation capacity of the renewable-energy-source generators will increase very quickly, the proportion of the big units with capacity of 600 MW and above in the thermal power generation unit will be over 50%, the coverage rate of the desulfurization equipment and the denitration equipment will be over 95% and 80% respectively, and the potential capacity of Efficiency Power Plant (EPP) would be accounting for about 10% of the conventional installed capacity calculated according to the Integrated Resource Strategy Planning (IRSP) model. In the following decade, some indicators of power industry would be in the international advanced level, which promote the national economic and social sustainable development in the aspect of the technology and management, etc.

Key words: Power Industry, Energy Conservation, Emission Reduction, Technology, Management, Sustainable, Development, Low Carbon, Environmental-friendly, Integrated Resource Strategy Planning (IRSP)

1. Introduction

The power industry is the basic industry of the national economy, and provides support for economic and social development and living standards improvement. In China, the power industry is the main energy consumer and key energy-saving industry. The annual energy consumption for power generation is more than 40% of the energy consumption of the whole society and the SO_2 emissions in power industry is more than 50% of the SO_2 emissions of the total industries.

For a long time, Chinese power enterprises have insisted to the policy of *"thinking much of both exploitation and conservation, and putting conservation at the first place"*. During the "Eleventh Five-Year Plan" period (2006-2010), the Chinese power enterprises have further strengthened the power structure adjustment, gave priority to the development of generators with large-capacity and high-efficiency, focused on the spread of energy-saving technology, improved management faculty, and so on. Accordingly the coal consumption rate for power generation and supply, line loss rate and other energy consumption indexes have decreased, resulting in remarkable energy conservation and emission reduction, positive contribution to the sustainable economic and social development of the country. In the future, the power industry will keep on playing an important role in energy conservation and emission reduction, and promoting the economic and social sustainable development of the country.

2. The achievements of energy conservation and emission reduction in power industry

2.1 Power industry overview

At the end of 2011, China's power generating capacity exceeded 1000 GW and reached 1056 GW, wherein the thermal power was 765 GW, accounting for about 72.5%; the hydro power was 231 GW, accounting for about 21.8%; the nuclear power was 13 GW, accounting for about 1.2%; and the wind power was 45 GW, accounting for about 4.3%. The loop length of the transmission line of 220kV and above has reached nearly 0.50 million km. The substation equipment capacity has reached 2200 GVA [1]. At present, China's power generation and grid scale have been the first in the world wherein the hydropower and wind power installed capacity is the first in the world, and the nuclear power construction capacity accounts for 40% of the world [2].

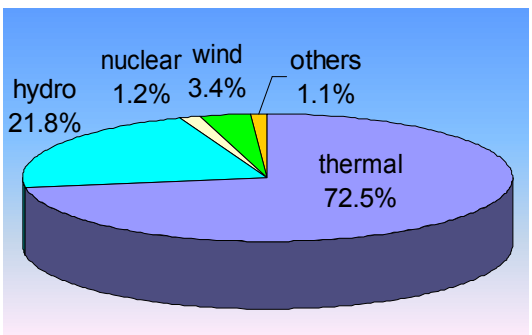

Figure 1 Structure of Chinese generating capacity at the end of 2011

Clean energy has been developed rapidly and the power structure has been gradually optimized. In recent years, the hydro power, nuclear power, wind power and other clean energy is developing rapidly, especially the wind power which is in the trend of doubling every year. From 2005 to 2011, the installed capacity of hydro power, nuclear power, wind power and other clean energy has increased from 126 GW to 288 GW with an average annual growth rate of 14.8%. In 2011, the installed capacity of slime, coal gangue power generation was 26 GW, an increase of approximately three times more than that in 2005.

Large units have been developed and small ones have been suppressed in steady progress, the average capacity of thermal power has been largely upgraded. In recent years, China has shut down a large number of inefficient, backward, energy-inefficient, and small thermal power units, and set up a number of high-capacity, high-parameter, and high-efficiency ones. At the end of 2010, the number of the ultra-supercritical units with capacity of 1000 MW has exceeded over 30, the proportion of thermal power units with capacity of 300 MW has accounted for more than 70% of the thermal power installed capacity, the average capacity of thermal power has reached 108.8 MW, about two times of that in 2005 (60.9 MW).

Promotion of desulfurization equipments has been speeded up; the total emission of SO_2 has reduced. In recent years, China has increased efforts on the construction of desulfurization equipments. At the end of 2010, 578 GW coal-fired units have been equipped with desulphurization equipments, accounting for 89% of the total coal-fired installed capacity. The SO_2 emission of per unit thermal power production has decreased more than 60% than that in 2005. In the case of the power output has increased by 70%, the SO_2 actual net emissions reduction was about 4 million ton during the “Eleventh Five-Year Plan” period.

National network has been initially formed; benefits from large grid gradually have been achieved. Currently, all provinces except Taiwan have been networked thus laying a foundation for the national large-scale optimization and allocation of power resources. Furthermore, there was a substantial increase in trans-regional trading power. In 2001, the trading volume was only 2.3 TWh. It increased to 77.4 TWh in 2005. In 2010, it further increased to 149.2 TWh. Southeast Shanxi - Nanyang – jingmen (1000 kV), Xiangjiaba - Shanghai (± 800 kV), Yunnan - Guangdong (± 800 kV) and other UHV AC or DC projects were put into operation, that creates a good situation for building a strong and smart grid.

2.2 Key energy consumption indicators

2.2.1 Net coal consumption rate for power supply

Net coal consumption rate for power supply of thermal power plants is a comprehensive reflection of net coal consumption rate for power generation and auxiliary power rate. It reflects both the level of fuel consumption in thermal power generation and the energy consumption of the power plant itself.

During the “Eleventh Five-Year Plan”, along with the building of a large number of new large capacity units, the technological renovation of old units and the close of small units, the level of technical equipment of the power generation industry as a whole has been greatly improved, and the technical and economic indicators have been gradually improved. The net coal consumption rate for power supply has decreased from 370 gce / kWh in 2005 to 333 gce / kWh in 2010, a drop of 37gce/kWh and a decrease of 10%. In 2011, it further reduced to 330 gce / kWh, reaching the world advanced level [1].

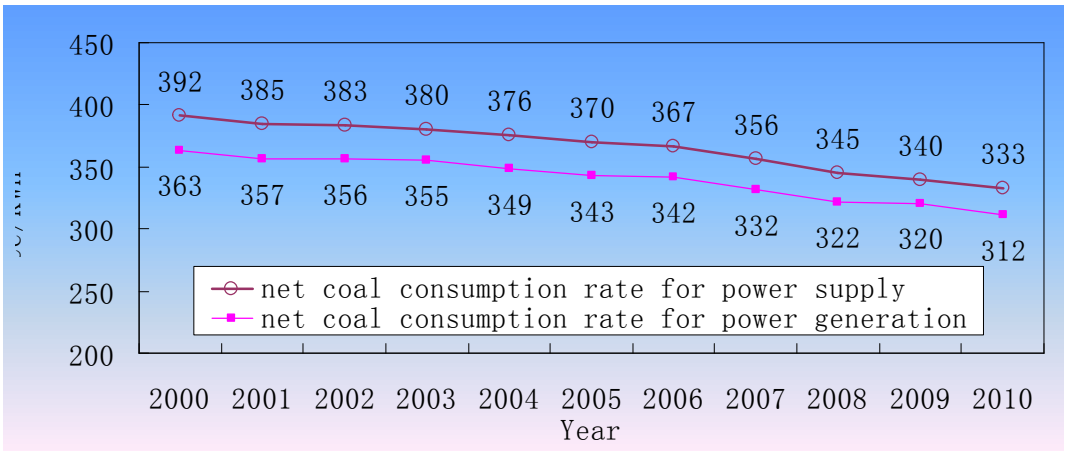

Figure 2 Changes of the net coal consumption rate of Chinese thermal power units

Net coal consumption rate for power supply is closely related to unit capacity and performance parameters. In general, the larger the capacity of the units is, the higher the efficiency and the lower the net coal consumption rate is. Table 1 shows the net coal consumption rate for power supply of units with different capacity in 2010.

Table 1 Net coal consumption rate for power supply of units with different capacity in 2010 [1]

Capacity of the unit / MW	Net coal consumption rate for power supply / gce/kWh
below 100	363
100-200 (excluding 200)	358
200-300 (excluding 300)	348
300 - 600 (excluding 600)	330
600-1000 (excluding 1000)	317
1000 and above	293

Compared with the units with capacity of 300-600MW (excluding 600), the net coal consumption rate for power supply of units with capacity of below 100MW was 33 gce/kWh higher. It indicates that increasing the average capacity of the generator units may significantly reduce the auxiliary power rate and net coal consumption rate for power supply.

2.2.2 Line loss rate

Line loss rate reflects the electricity or energy loss in many parts including power transmission, transformation, distribution and marketing. It is a comprehensive reflection of the grid structure, production, equipment performance, management faculty and so on.

Since the reform and opening up, the power industry has developed rapidly. Due to the grid structure strengthened continually, equipment performance improved continually, energy-saving technology extended continually, management faculty gradually intensified, proportion of secondary industry power

consumption rising and other factors, the line loss rate has generally shown a downward trend, from 9.64% in 1978 to 6.53% in 2010, a decline of 3.11 percentage. In 2011, it further reduced to 6.31% [1].

During the "Eleventh Five-Year Plan" period, China's line loss rate has fallen by 0.68 percentages, a decrease of 9.4%. It further decreased by 0.22 percentages in 2011. Especially under the situation of the slowdown of high energy-consuming industries with higher loading rates, as well as the rapid development of tertiary industries and residential power consumption with lower loading rates, the Chinese line loss rate remains the downward trend, thus making a significant contribution to the cause of energy conservation.

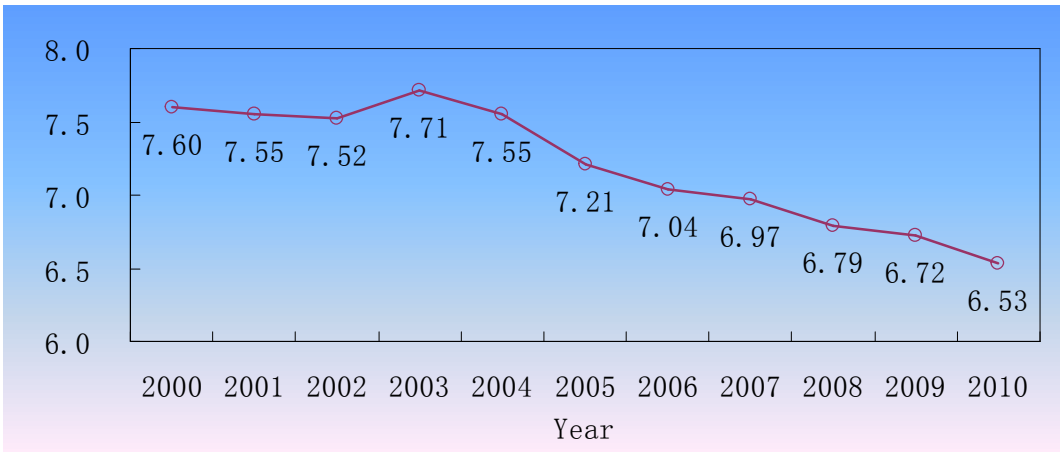

Figure 3 Changes of China power grid line loss rate

From the point of different grids, the line loss rate of the State Grid Corporation of China (SGCC) and China Southern Power Grid (CSG) have been lower than that of the local grid, and been with a significant downward trend. Since the policy of “power plants separated from power grids” was carried out, the line loss rate of SGCC has decreased from 6.97% in 2003 to 6.38% in 2010. The line loss rate of CSG has decreased from 7.47% in 2003 to 6.28% in 2010. Local grid line loss rate is generally 10% or more. In some areas, it is even more than 20%.

2.3 Benefits of energy conservation and emission reduction

During the “Eleventh Five-Year Plan” period, the energy consumption intensity has decreased significantly with a significant benefit as the power enterprises have taken a number of technical and management measures. Table 2 shows some key indicator of the power industry changes during the “Eleventh Five-Year Plan” period.

Table 2 several key indicators of the power industry [1]

	Unit	2005	2006	2007	2008	2009	2010
Net coal consumption rate for power supply	gce/kWh	370	367	356	345	340	333
Net coal consumption rate for power generation	gce/kWh	343	342	332	322	320	312
Auxiliary power rate	%	5.87	5.93	5.83	5.9	5.76	5.43
Wherein: the thermal power	%	6.80	6.77	6.62	6.79	6.62	6.33
Line loss rate	%	7.21	7.04	6.97	6.79	6.72	6.53

Compared with the target value of the “Eleventh Five-Year Plan”, the net coal consumption rate for power supply, the water consumption for power generation, the SO_2 emissions, and the comprehensive line loss rate indicators are all completed ahead of schedule, as shown in Table 3.

Table 3 Energy-saving and emission reduction targets completion of the power industry in the "Eleventh Five-Year Plan" [2]

Indicator	unit	Reference value in 2005	2010		
			Target value	Actual value	Target completion
Net coal consumption rate for power supply	gce/kWh	370	355	333	Achieved in 2008
Comprehensive line loss rate	%	7.21	7.00	6.53	Achieved in 2007
Water consumption for power generation	kg/kWh	3.10	2.80	2.45	Achieved in 2008
SO_2 emissions of Power industry	million ton	13.50	9.52	9.56	Achieved in 2009
Desulfurization units operation capacity	GW	53	408	over 500	Achieved in 2008
Comprehensive utilization rate of industrial solid waste	%	55.8	60.0	68-69	Achieved in 2008

Take the capacity of the units, the level of technology, and the desulfurization in 2005 as references, the primary energy saved in 2010 was 120 million tce, the alternative fossil fuels saved were 110 million tce, and the SO_2 emission reduced was 3.9 million ton. During the "Eleventh Five-Year Plan" period, the accumulated amount was 298 million tce, 290 million tce and 9.7 million ton respectively.

During the "Eleventh Five-Year Plan" period, China's energy consumptions per GDP have dropped by 19.1%, the SO_2 emission has decreased by 14.29%. We have basically completed the objectives and tasks in the Outline of the Eleventh Five-Year Plan Chinese Economic and Social Development. From the point of energy saving, benefiting from a decline in energy consumptions per GDP, we have achieved energy saving of 760 million tce in 2010 compared with 2005, wherein the power industry with a contribution rate of 15.7%. From the point of SO_2 emission reductions, the national emission has reduced by 3.64 million ton in 2010. Due to the substantial increase of the desulfurization equipment installed, the contribution rate of the power industry is over 100%.

2.4 Power enterprises' experience in energy conservation and emission reduction

Energy conservation is a long-term strategy for energy development in China. The power companies, especially the central ones, have conscientiously implemented the national energy development strategy, conducted energy conservation and emission reduction from technology, management and other aspects. They have focused on improving the technical level, promoted the upgrading of the structure, promoted and applied the new energy-saving technologies and products, established a comprehensive and systematic energy management system and index system, set up many Energy Service Companies (ESCo), improved the level of energy saving, made remarkable achievements, and accumulated a lot of experience. The main is as the following:

- **Actively adjust power and unit structure**

In accordance with the government requirements, positive develop and construct hydropower (small hydropower is renewable energy), wind power, solar and other renewable energy; vigorously develop and construct energy-saving units with high-capacity, high-parameter, high efficiency; develop thermoelectric cogeneration units; eliminate small thermal power units; optimize the structure of the total power units and thermal power units. During the "Eleventh Five-Year Plan" period, China's total closed small thermal power installed capacity has reached 77.26 GW, accounting for 10.9% of the total installed capacity of thermal power. The average capacity has nearly doubled which has significantly improved the power generation efficiency of thermal power units.

- **Attach importance to energy-saving technological reformation**

Encourage the scientific research on technological progress; actively promote the application of mature

and reliable technologies, processes, methods, especially the energy saving or environmental-friendly ones for saving land or reducing the consumption of water, electricity, oil and so on. Modernize the flow passage component of the turbine; promote plasma ignition, micro-oil ignition, small oil gun technology on boiler ignition system; innovate the power fans and pump auxiliary equipment with the speed or frequency adjusting technology; conduct water-saving technology reformation of power plant; optimize and strengthen the grid structure; implement intelligent substation and typical design of transmission lines; promote large cross-section lines; promote the usage of amorphous alloy transformers and single-phase transformers.

- **Strengthen the comprehensive utilization of resources**

In accordance with the principle of "reduction, reuse, recycling", actively develop cogeneration to improve the utilization rate of waste air, water, heat and pressure, vigorously promote the comprehensive utilization of fly ash, and actively carry out industrial wastewater "zero drainage"; actively adopt air cooling technology in areas with abundant coal and deficient water; develop and utilize biomass energy to reduce the consumption of fossil energy. According to estimates, the thermal efficiency of cogeneration is 30% higher than that of the separate generation of power and heat. During the "Eleventh Five-Year Plan" period, the new capacity of cogeneration units can realize annual energy saving of about 43 million tce.

- **Promote the nationwide inter-regional electricity trading**

In recent years, China's inter-regional and inter-provincial network scale has kept on expanding; the power transmission capacity is continuously improving, thus providing a good platform for the mutual-aid of thermal and hydro power, mutual-compensation of different drainage area, satisfying utilization of clean energy, and optimal allocation of resources. On one hand, it reduces disposable water, makes full use of hydropower, satisfying utilizes wind power and other renewable energy; on the other hand, it eases the strain between power supply and demand in some areas and the resource and environmental pressure in eastern areas in China. In 2011, China's inter-regional and inter-provincial power trading is completed 624 TWh, wherein the inter-regional power trading is 266.4 TWh and the inter-provincial power trading is 357.6 TWh [2].

- **Actively promote the construction of the high-voltage transmission grid**

The transmission capacity of a 1000kV AC line can reach 4-5 GW, 4-5 times of that of a 500 kV AC line, while the theoretical loss of a 1000kV AC line is only 1/4 of that of a 500kV AC line. At the end of 2010, China's UHV transmission line length has reached 4340 km, providing a broad prospect for the optimization of a wide range of resources.

- **Actively develop power trading and energy-efficient scheduling**

By optimizing the utilization of hydropower, sorting thermal power by energy consumption intensity, encouraging hydropower units and large capacity power units to take place of low-capacity thermal power units, building an open and transparent trading platform and other measures, keep on improving the Generation Rights Trading Mechanism (GRTM). Since the GRTM carried out in 2007, SGCC had completed accumulated trading power of 438.3 TWh up to the end of 2010, the benefit is shown as that about 40.26 million tce coal is saved, 100 million ton CO_2 and 1 million ton SO_2 emission is reduced [3].

- **Strengthen the guarantee of the full acquisition of renewable energy power**

SGCC attaches great importance to the development of clean energy such as wind power. Taking effective measures to overcome the difficulties brought by the intermittent and anti-peaking characteristics of wind power to the grid, SGCC fully buys the wind power and other renewable on-grid energy in the area covered by the company grid under the condition of ensuring the safe operation of power grids. During the "Eleventh Five-Year Plan" period, SGCC has transmitted accumulated about 2500 TWh renewable energy. It is estimated that it has achieved coal savings of about 700 million tce, CO_2 emission reduction of about 2000 million ton, and SO_2 emission reduction of about 13 million ton [3].

In addition, the power generation companies and power grid enterprises strengthen internal management faculty, benchmarking analysis, appraisal motivation, and continue to tap the energy potential; establish Supervisory Information System (SIS) in the power plant to achieve power generation production process monitoring, unit performance computing, unit load optimizing and scheduling, economic indicators analyzing, operation instructing and so on; comprehensively build an online real-time flue gas emissions monitoring system for coal-fired units to conduct real-time monitoring and early warning of the operation rate and desulfurization efficiency indicator of the desulfurization facilities;

carry out power system economic operation, optimize the scheduling operation ways, and strengthen the operation and management of the reactive-load compensation equipment; actively promote and improve the power line loss management system for real-time monitoring and analysis to improve the automation and information level of the line loss management; establish Energy Service Companies (ESCo), implement demand side management (DSM), improve energy usage efficiency and optimize the power consumption; conduct partial pressure statistical work with target, regularly and from time to time carry out theoretical calculations of line loss, detect weaknesses and provide basis for the targeted loss reduction work through comparison and analysis of the statistics.

3. The trend of energy conservation and emission reduction in power industry

The next decade will be a critical period for the comprehensive building of a well-off society in China. The country will further increase energy conservation and emission reduction efforts and put forward the "Twelfth Five-Year Plan (2011-2015)" energy conservation and emission reduction goals based on the effects of the "Eleventh Five-Year Plan". The energy saving technology and equipment as well as management means are becoming more and more, thus creating a good external condition for energy conservation and emission reduction work. According to the *"Twelfth Five-Year Plan on Energy conservation and Emission Reduction"* issued by State Department of China on 6th August 2012, the net coal consumption rate for power supply of thermal power industry in China in 2015 would be expected decreased to 325gce/kWh, a decrease of 8 gce/kWh compared with 2010; the grid line loss rate would fall to 6.3%, a decrease of 0.23 percentage. In the case of power generation increasing by 50%, the SO_2 emission would have a net decrease of 1.56 million ton, a decrease of 16%, and the NOx emission would have a net decrease of 3.05 million ton, a decrease of 29%.

From the point of the energy saving in the power generation, the main factors promoting the decline of the net coal consumption rate for power supply are power structure optimization, energy-saving technological renovation and management faculty improvement; while installation of desulfurization and denitrification equipment, use of air cooling technology, and decline in grid load rate have adverse effects on the decrease of the net coal consumption rate for power supply. A coal unit, when installed with desulfurization and denitrification equipment, the net coal consumption rate for power supply shall increase by 4-6 gce/kWh; when use air cooling technology, the increment is about 15-20 gce/kWh. The test data of a 300 MW coal unit shows that, if the power generation load rate decreases from 100% to 80%, the net coal consumption rate for power supply will increase about 3 gce/kWh; if the power generation load rate decreases from 80% to 60%, the net coal consumption rate for power supply will increase about 17 gce/kWh; if the power generation load rate decreases from 60% to 40%, the net coal consumption rate for power supply will increase about 29 gce/kWh.

From the point of the energy saving in the grid, the main factors promoting the decrease of line loss rate are grid structure reinforcement, new energy-saving technologies and equipment promotion, reactive power optimization and management faculty development; while the close of the small thermal power units, changes of power structure, and reformation of power generation scheduling mode may promote the energy efficiency of the whole community as well as adversely affect the decline of line loss rate. Most of the small thermal power units are accessed to the grid in 110kV and below. The close of the small thermal power units may result in the reduction of the local power balance, and the regional load shortfall had to be supplemented by the 220kV line. Therefore, it is bound to increase the intermediate link of the power transmission and part of the grid power losses. The line loss rate of iron and steel, non-ferrous metals, building materials, chemicals and other high energy-consuming industries is low while the line loss rate of resident and the tertiary industry is high. The power consumption proportion of high-energy-consuming industries will drop in the future, thus promoting the increase of the line loss rates. Generation rights trading, energy-saving power generation scheduling may achieve energy conservation from the power generation aspect, as well as increase the line loss rate as the power flow distribution is not optimal.

We can see that there is still a big energy saving potential in power industry. However, there also exist some difficulties in the completion of the "Twelfth Five-Year Plan" energy conservation and emission reduction targets. In order to safeguard the countries successfully completing the targets and achieving sustainable economic and social development, power companies need to overcome a lot of difficulties, further strengthen management tools, upgrade conduct technological, optimize the power structure, build a smart grid, adhere to both the coal transportation and power transmission, enlarge inter-regional transmission channel, innovate generation rights trading model, improve the energy-efficient scheduling mechanism, continue to promote the national energy conservation and emission reduction work while achieve its tasks at the same time.

It is predicted that by 2020, China's power generation capacity will reach about 2000 GW, wherein the total of hydropower, nuclear power, wind power capacity shall account for about 40% of the total installed capacity; the proportion of the big units with capacity of 600 MW and above in the thermal power generation units will be over 50%; the coverage rate of the desulfurization equipment will increase to more than 95%, and that of the denitration equipment will increase to about 80%. Regarding the trans-regional interconnection and Efficiency Power Plant (EPP) as a restriction of the Integrated Resource Strategy Planning (IRSP) model [4, 5], we can also make a quantitative analysis which illustrates that the cross-regional power transmission and EPP can reduce the installation capacity and further realize the social benefits while maintaining the power supply of each region. In 2020, the EPP potential would be 200 GW, account for 10% of the installation capacity of the Common Power Plant (CPP). In the next decade, some indicators of power industry would be in the international advanced level and continue to help China's sustainable economic and social development from the aspects of technology and management.

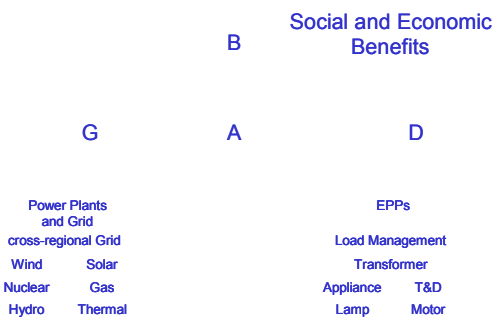

Figure 4 IRSP Model

4. Conclusion

Bounded by the constraints of energy resources and climate and environmental factors, China will follow a new road of sustainable development. Energy conservation and emission reduction shall be the theme for a long term. Despite the difficulties, the power industry will continue to play an important role in energy conservation and emission reduction. It is suggested that government departments should encourage power companies to carry out the following work, and make efforts to promote the effective development of the power industry and the national energy conservation and emission reduction work:

1) Vigorously develop hydropower, nuclear power, wind power and other renewable energy projects, further optimize the power structure.

2) Actively construct large thermal power plant groups, hydropower groups, and nuclear power groups, and rationally plan the power plant and grid.

3) Rationally develop large-scale efficient environmental-friendly thermal units and thermoelectric cogeneration units to improve the overall efficiency of power generation.

4) Further improve the power grid technology, accelerate the construction of a strong and smart grid, and strengthen the platform advantages in optimization of the allocation of resources.

5) Actively develop efficient and clean coal-fired power generation equipment, high-voltage power transmission equipment, large-scale circulating fluidized bed boiler, large wind turbines and other advanced and applicable technologies to enhance the technical level of the power industry.

6) Promote energy-saving power generation scheduling and GRTM to improve the overall efficiency of power industry.

7) Establish a sound supervision and management mechanism for energy conservation and emission reduction, speed up amendments to the relevant laws and regulations and industry standards, establish

a price formation mechanism, and guide the whole society to energy conservation and emission reduction.

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