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Feasibility Research of Reach Energy Efficiency Standards of Major Industry Energy Consumption Products

China National Institute of Standardization

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（Ⅰ）Project introduction

Industries consume the majority of China’s energy—their power consumption accounts for over 70% of the national annual power output. The Chinese government has laid great importance on energy savings in industries. As Chinese industrialization progresses, industrial power consumption will remain in first place. Because there are different energy efficiencies and evaluation methods for energy-consuming products (such as motors, pumps, air compressors, transformers, industrial boilers, etc.) and “reach”[1] energy efficiency standards have already been set for some of these products, this project only involves fans, pumps, and air compressors.

These three are the main energy-consuming equipment in Chinese industry and are widely used in petroleum refining, chemical production, coal and mineral mining, power production, metallurgy, urban construction, and other industries (and also environmental protection). Experts estimate that the power consumption of these products accounts for about 40% of the annual national power output and their motor capacities account for about 60% of the annual national rated motor capacities. Respectively, the power consumption of pumps, fans, and air compressors accounts for 20%, 10%, and 10% of the annual national power output. Compared to developed countries, Chinese products waste more energy because of worse performance and lower energy efficiency. Furthermore, there has been an energy resource shortage in China in recent years and power supply usually cannot meet the demand. In 2004, the power supply in over 24 provinces had to be cut off to limit power consumption during peak hours. It’s an urgent task for the Chinese government to place more importance on saving energy and improving the energy efficiency of industrial energy-consuming products.

So far, China has developed and completed a series of energy efficiency standards for many important energy-consuming products in industrial sectors. The energy efficiency standard for motors was implemented in 2002, while one for displacement air compressors was issued in May 2003 and implemented on Nov. 1, 2003. The energy efficiency standards for clean water

[1] A “reach” energy efficiency standard is one that provides a stretch (reach) target for manufacturers to meet. Reach standards provide more energy savings than conventional standards but relative to conventional standards, manufacturers generally need more time and assistanc before reach standards can take effect.

centrifugal pumps and ventilating fans have been publicized and will be formally issued soon. However, most of these standards are the status quo standards, which usually come into effect half a year after their publication. The indexes in these standards are usually lower than desired. Research on reach energy efficiency standards is on the agenda to achieve the effect of energy saving through standards, establish milestones for the development of enterprises, and encourage the technical innovations of enterprises. At present, we are organizing the study of reach energy efficiency standards for motors funded by the American Energy Foundation and CLASP. Moreover, the feasibility study project of reach energy efficiency standards for fans, pumps, and air compressor has obtained kind help from the David and Lucile Packard Foundation and the William and Flora Hewlett Foundation. The project term is from July 2004 to Jan. 2005, with the project funding code of G-0404-07383. The executive unit of the contract is the China National Institute of Standardization. The project has also got a large number of help from associated organizations such as National Testing Center of Compressor and Rerfrigerator Products, International Copper Association, and so on. We deeply appreciate their initiative and dedication.

The project's objectives include the investigation, research, and forecasting of the market for fans, pumps, and air compressors; model analysis of the energy-consumption and economic benefits of energy saving; energy efficiency of related foreign products; drafting reach energy standards; analyzing executive obstacles; drafting a timetable of energy savings; and feasible policy suggestions and measures.

（Ⅱ）Main Working Stages

The feasibility research of the reach energy efficiency standards was separated into four stages.

Stage 1: Collecting and analyzing related documents both at home and abroad. Consulting the statistics information, industry reports, academic theses, product manuals, and related books from authoritative domestic statistic organizations like the State Statistic Bureau, the Machinery Industry Association, and the State Information Center, etc. Investigation mainly focused on the general survey of the trade, and the output and supply-demand status of fans, pumps, and air compressors. Upon the collection and analysis of a vast amount of statistical data, we determined the analytical objects: the clean water centrifugal pumps, ventilating fans, and displacement air compressors that are dominant in the pumps, fans, and compressors trades. Moreover, the project team investigated the situation of the foreign corresponding trade, collecting and researching related product standards, especially the energy efficiency standards, product technical innovation, and the governmental policies and measures to market the products of high energy efficiency.

Stage 2: Investigating the market throughout the country. The Research Institute trusted an authoritative survey company in China (Beijing Up-Point Consulting Co., Ltd.) to conduct the thorough survey of domestic manufacturers of fans, pumps, and air compressors. The investigative objects were mainly large and medium-sized manufacturers. The key parameters of the survey were average driving power, typical product life, specifications of high energy efficiency products, advanced production technologies, attitudes toward increasing a product's energy efficiency, and so on. It was a qualitative survey because it involved only three types of main energy-consuming products among mass investigative contents and the project fund was limited. The quantitative of key parameters in the analytical model was determined in accordance with the statistical information from the State Statistic Bureau and the opinions of experts.

Stage 3: Setting the technique indexes and model analysis. The reach energy efficiency indexes are first set according to the market survey information, materials from the State Statistic Bureau, experts' opinions, and the existing energy efficiency standards. Then the model analysis was conducted to test the rationality of these indexes.

Stage 4: Drafting the research report. After comparing the energy-saving potentialities of the three types of products and their technical feasibility based on the above investigation and analysis, the drafting order of the reach energy efficiency standards was arranged. The drafting and executive obstacles of reach energy efficiency were analyzed. The policy suggestions and measures were put forward and the study report was drafted, modified, and perfected.

（III） Project Implementation Result Forecasting

Fans, pumps, and air compressors are general machineries, and they take a very important place in all economic industries in China. The prominent feature of such products is their mass production and wide application. Compared with those in developed countries, China's products of fans, pumps, and compressors have lower technical content and much room to be improved. The environmental effects that could result from energy savings are tremendous. Based on the energy efficiency standards in effect (or upon publication), if the evaluating values of clean water centrifugal pumps and displacement air compressors are taken as the minimum allowable in their reach energy efficiency standards and the design-point efficiency of ventilatiion fans is taken as the minimum allowable in the reach energy efficiency standard, according to the energy-saving model analysis, the power saved by the clean centrifugal pumps by 2020 will accumulate to 343.72 TWh, i.e., 127.89 million tons of standard coals by when the reach energy efficiency standards are implemented in 2008. The accumulated pollutant emission reduction resulting from energy saving by 2020 will be 96.66 million tons of carbon, 1.51 million tons of nitrogen oxide, 2.17 million tons of sulfur dioxide, and 9.22 million tons of particles. In addition, the peak demand value will also be reduced by 200.24 GW. For the ventilating fans project, it is estimated that the saved power will accumulate to 124.87 TWh by 2020, i.e., 46.47 million tons of standard coals. The accumulated pollutant emission reduction resulting from energy saving by 2020 will be up to 35.12 million tons of carbon, 0.55 million tons of nitrogen oxide, 0.79 million tons of sulfur dioxide, and 3.35 million tons of particles. The peak demand value will also be reduced by 56.74 GW at the same time. For the displacement air compressors project, it is estimated that the saved power will accumulate to 116.59 TWh by 2020, i.e., 43.40 million tons of standard coals. The accumulated pollutant emission reduction resulting from energy saving by 2020 will be 32.79 million tons of carbon, 0.51 million tons of nitrogen oxide, 0.74 million tons of sulfur dioxide, and 3.13 million tons of particles. The peak demand value will also be reduced by 54.18 GW. See Table 0-1 and Figure 0-1 for details.

Table 0-1: Project Energy Saving Capacity Forecast（MMTce）

Year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
CCP	0.65	1.98	3.38	4.86	6.41	8.05	9.77	11.58	13.49
VF	0.24	0.73	1.24	1.78	2.34	2.93	3.60	4.22	4.91
DAC	0.24	0.73	1.28	1.89	2.31	2.77	3.28	3.85	4.30
TOTAL	1.13	3.44	5.90	8.53	11.06	13.75	16.61	19.65	22.70
Year	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
CCP	15.51	16.42	17.38	18.40	16.44	13.05	9.07	5.40	2.68
VF	5.63	5.95	6.29	6.65	5.94	4.72	3.28	1.95	0.97
DAC	4.79	5.34	5.96	6.65	5.41	3.50	1.77	0.75	0.28
TOTAL	25.94	27.72	29.64	31.70	27.79	21.27	14.12	8.10	3.93
Year	**2026**	**2027**	**2028**	**2029**	**2030**				
CCP	1.06	0.32	0.06	0.01	0				
VF	0.38	0.11	0.02	0.002	0				
DAC	0.07	0.01	0						
TOTAL	1.52	0.44	0.09	0.01	0				

Note: CCP stands for clean water centrifugal pumps; VF stands for ventilation fans; and DAC stands for displacement air compressors.

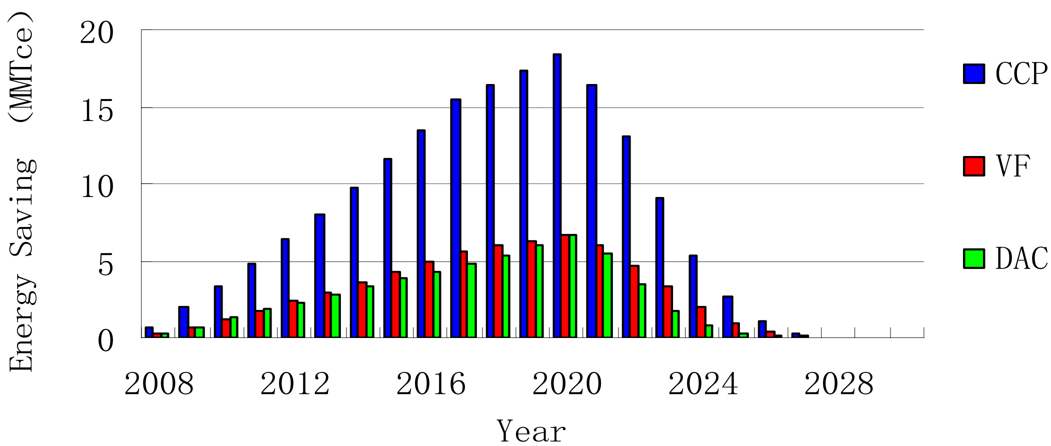

Figure 0-1: Project Energy Saving Capacity Forecast（MMTce）

It is evident that improving the energy efficiency standards of ventilating fans, clean water centrifugal pumps, and displacement air compressors can save a great amount of energy. China badly lacks in energy supply at the moment. People throughout the country are active in forming a national energy-saving policy and conducting energy-saving actions. It is of great significance to formulate the reach energy efficiency standards of the main energy-consuming products to regulate markets, promote technological innovations, and finally realize the energy-saving goal.

The developing order of the reach energy efficiency standards of the three types of products was comprehensively analyzed based on the present technical level, opinions of manufacturers and experts, and the analyzing results of engineering and economic models. Based on this information, clean water centrifugal pumps are to be developed first, then ventilating fans, and then displacement air compressors.

（Ⅳ）Policy Suggestions

The formulation and implementation of energy efficiency standards will promote technical innovation, regulate markets, and ensure economic sustainable development only if they are combined with supporting policies and measures. The government should pay close attention to perfecting supporting energy policies such as eliminating high energy-consuming products, establishing effective energy-saving supervising and administrating systems, developing financial and other encouraging policies, and improving customer material and training.

Moreover, considering that the international mature energy efficiency standards of fans, pumps, and air compressors are not available and the domestic general machinery manufacturing technologies are not advanced, the government should reinforce the support for product researching; build researching bases and information platforms for common energy-saving technologies and general machineries; encourage the development, import, and absorption of high and new technologies; reorganize the existing product performance information and data; and therefore provide strong support for the formulation and implementation of the reach energy efficiency standards for fans, pumps, and air compressors, enterprise technical innovations, and the overall transition of high energy efficiency product models.

1 Foreword

1.1 Current situations of energy and environment

Following the fast development of Chinese economy, the serious power, coal, and oil shortages have become the universal focus of the whole society. The imbalance between energy supply and demand is more and more critical. The energy has become one of the bottlenecks that restrict the construction of the all-around well-off society and the sustainable development of the national economy. In 2003, China produced 1.667 billion tons of coal and 170 million tons of oil, and imported 100 million tons of oil. The national total installed capacity reached 385 million kW, increased by 7.8% as compared with the previous year. The national total power output reached 1908 billion kW, increased by 15.3% as compared with the previous year. The equipment operation hours of the power plants of 6000 kW and above reached 5250 hours, increased by 390 hours as compared with the previous year. On the other hand, Chinese economy continued to develop at high speed. The GDP reached 11700 billion yuan, increased by 9.1% as compared with last year. The Chinese GDP per capita exceeded 1000 USD in accordance with the current exchange rate. The high speed economic development extremely stimulated the energy demand. The imbalance between the limitability of energy resources and the demand by social and economic development was fully activated. Over 20 provinces had to cut off their provincial power grid to limit the power supply. Especially in peak hours in summer, the oil, coal and power supply were extremely urgent and short. Both the industrial and agricultural productions and people’s daily living were severely influenced.

Most of Chinese energy consumption is coal, so that the environmental problems become more and more serious. In 2002, China consumed 1.42 billion tons of coal, increased by 34% as compared with year 1990. The average annual increase rate is 2.5%. Over 70% of the raw coals are directly burned without coal washing and separation. The emission of sulfur dioxide, smoke, and dust due to coal burning accounts for 70~80% of the total emission. The acid rain area resulting from sulfur dioxide emission accounts for one-third of the total national land area. The carbon dioxide emission from fossil fuels is the main source of greenhouse gases. According to the 2003 report by the China Environmental Protection Administration, the pollution of sulfur dioxide, particles, and acid rain was very serious and its level rise again. In 2003, the sulfur dioxide emission reached 21.587 million tons, a 12.0% increase, reaching the highest level since 1999.

Table 1-1: Chinese SO_2 Emission in Exhaust Gas unit: 10^4 tons

Year	SO_2 emission		
	Total	Industry	Living
1999	1460.1	397.4	1857.5
2000	1612.5	382.6	1995.1
2001	1566.6	381.2	1947.8
2002	1562	364.6	1926.6
2003	1791.4	367.3	2158.7
Annual floating rate (%)	14.7	0.6	12

Source: Annual report (2003) of State Environmental Protection Administration

The total smoke and dirt emissions of China in 2003 were 10.487 million tons, increased by 3.6% as compared with last year. The industrial smoke and dirt emissions were 8.462 million tons, accounting for 80.7% of the total emission and increased by 5.2% as compared with last year.

Table 1-2: Chinese Particulates Emission in Exhaust Gas unit: 10^4 tons

Year	Soot Emission			Industry Powder
	Total	Industry	Living	
1999	1159	953.4	205.6	1175.3
2000	1165.4	953.3	212.1	1092
2001	1069.8	851.9	217.9	990.6
2002	1012.7	804.2	208.5	941
2003	1048.7	846.2	202.5	1021
Annual floating rate (%)	3.5	5.2	-2.9	8.5

Source: Annual report (2003) of SEPA

The rainfall monitoring results of 487 cities (counties) indicate that the average annual rainfall ph value was from 3.67 (in Pingxiang City, Jiangxi Province) to 8.40 (Jiayuguan City, Gansu Province). Compared with last year, the cities with acid rain increased by 4.1% and the cities with average annual ph value equal to or lower than 5.6 increased by 4.7%, and the cities with average annual ph value lower than 4.5 increased by 2.8%. Cities with acid rain frequency of over 40% increased by 7.2%. The pollution of acid rain became more serious than the last year.

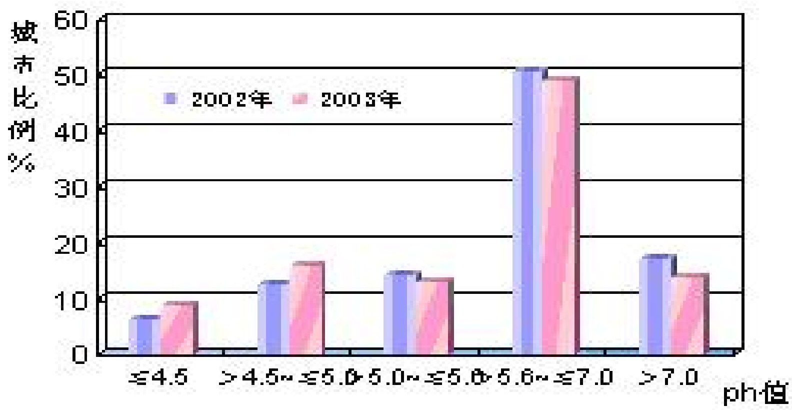

Figure 1-1: City Proportion of Different pH Values of Rainfall

1.2 Energy reserves and distribution

With a big land area, rich natural resources, and the absolute reserves of some normal energies of coal, petroleum, natural gas, hydropower in the leading places in the world, China's situation of primary energies is not optimistic because of its huge population. In 2000, the per capita remaining petroleum, natural gas, and coal reserves were only 26000 tons, 1074 cubic meters, and 90 tons, respectively, which were only 11.1%, 4.3%, and 55.4% of the world average value respectively. The per capita electricity consumption of China was only one-third of the world average value. The electricity shortage rate was 9.93% and would reach 15% by 2010, according to a report by the Japan Energy Research Institute. The petroleum reserves of China can last only dozens of years, while the coal can last only about 200 years.

Coal is in first place in China's energy consumption structure, then petroleum, hydropower, and natural gas. In 2002, the energy consumption structure was 66.1% of coal, 23.4% of petroleum, 2.7% of natural gas, and 7.8% of hydropower. Comparatively, the U.S. energy consumption structure in 2001 was 24.37% of coal, 38.69% of petroleum, 23.72% of natural gas, and 6.78% of hydropower. It is obvious that the coal proportion in Chinese energy consumption structure is very high, while proportion of quality energies is lower. This energy consumption structure results in low energy and economic efficiency (the heat efficiency of coal industrial boilers is 68%, while the heat efficiency of oil industrial boilers can reach 87%). Furthermore, Chinese energy reserves are unevenly distributed, with 60% of coal in North China and 70% of hydropower in Southwest China. The eight provinces and one city in South China are flourishing economically with concentrated industries and populations (37% of the national population), while the energy reserves are very low (only 2% of the total national coal reserves and 10% of the hydropower). The Chinese energy situation is critical because of the low per capita level, and unreasonable energy structure and distribution.

1.3 Energy utilization

The low energy utilization rate is another important factor for the Chinese energy demand increase. Calculated by technical energy efficiency indexes, the comprehensive energy efficiency of energy processing, transformation, storage, transportation, and final utilization has been raised from 26% in 1980 to 33% in 2000, but it is still 10% lower than that of developed countries. Calculated by economic energy efficiency indexes, the average unit energy consumption is 20%-80% (40% after weighted) higher than that of developed countries. For example, the coal consumption of power plants is 28% higher, the comprehensive energy consumption of large and medium-sized steel and iron plants and the large-sized synthetic ammonia plants is 25% and 40% higher, respectively. In 2001, the energy consumption per 100 million USD of GDP was about 110-120 thousand tons of standard coal, the unit energy consumption was 6.58 times as much as that in Japan, 4.49 times as much as that in Germany, 3.65 times as much as that in the U.S., 2.35 times as much as that in Brazil, and 1.24 times as much as that in India. China is one of the highest unit energy-consuming countries in the world. We can see from the above data that the energy waste in China is very serious while the energy saving potential is tremendous.

1.4 Energy demand forecast

China is the world’s largest coal consumer, and the second largest petroleum and power consumer next to the U.S. The next 20 years will be a critical period of China’s modernization and of transition of economic structure, urbanization, and consuming structure of people. It is estimated by experts that Chinese petroleum demand will reach 400 million tons by 2020 with an annual average increase rate of 12%. The proportion of the natural gas in primary energy will increase from the present 2.7% to over 10%. The foreign reliance of petroleum of China increased from 7.6% in 1995 to 31.0% in 2000 and will reach 60% by 2020, which is nearly equivalent to 58% of the U.S. The most optimistic estimation is that the general energy demand of China in 2020 will reach 2.5 billion tons standard coal, which increased by 90% compared with that in 2000. The most pessimistic estimation is 3.3 billion tons of standard coal and 152% increase. Energy saving and efficiency improvement are undoubtedly one of the most effective measures to ensure the national energy supply and maintain the sustainable development when the government formulates and implements many policies such as increasing energy exploitation, establishing smooth energy circulation systems, and adjusting the energy structures.

1.5 Governmental energy saving plan and focuses

The principle of “saving before development while valuing both developing and saving” has been implemented in China since the reforms and opening policies to the outside world. Over a long time, the energy saving in industries has been emphasized. The energy development and energy saving have made great progress. The energy efficiency has been increased remarkably. From 1980-2000, the 4.6% average annual increase of energy supported the 9.7% average annual increase of the national economy. The target of quadruple of economy increase with double of energy increase has been realized. The energy demand of the national economic development has been guaranteed.

The energy development strategy of China by 2020 can be stated briefly as energy saving priority, clean and environment friendly, safe supply, and market promotion. Energy saving is the core of Chinese energy strategy and policy. The terminal energy saving should be given first place. Guidelines encouraging these policies should be available. Energy saving in transportation, construction, and industries should be paid more attention. It will need a long time to adjust Chinese industry structure and high energy-consuming industries. Therefore, the energy consumption of industries will still be in first place in the long term, although the energy consumption of transportation and construction is increasing fast. Energy saving of industries will still be the focus of a national energy-saving plan.

2 Background information about the proposal of reach energy efficiency standards

2.1 Effect of the energy efficiency standards

Energy efficiency standards are one of the most important measures to improve energy efficiency of the terminal energy-consuming equipment all over the world in recent years. The high energy-consuming products are restricted on production, marketing, and importation by the energy efficiency standards, and eliminated from markets finally. After analyzing the experience of some developed places, such as the United States, European Union, Canada, and Australia, the positive effects of energy efficiency standards can be chiefly summed into the following points.

2.1.1 Alleviating the energy shortage and safeguarding the high speed development of the economy

To establish and implement energy efficiency standards for energy consumers has become one of the preferential policy tools in the world to improve products' energy efficiency, thereby saving energy and protecting the environment. China became a net energy importer after 1993 and thereafter increased its imported proportion year after year. Energy safety and energy saving are important preconditions to safeguard the achievement of the mid- and long-term economic target of our country. It is indicated by experts' analysis that 2657 TWh of electricity will be saved by 2020 if energy standards could be carried into execution. The saved power exceeds the total energy output all over the country.

2.1.2 Consummating the market economic system and boosting the enterprise technique progress

The implementation of energy efficiency standards rearranges the market and eliminates backward and high energy-consuming products on the one hand, and sets up the reach energy saving targets for enterprises on the other hand. It reminds the enterprisers that, only by keeping ahead on techniques in their own industry, can they remain invincible under the market economic system. It guides the enterprises development in the right direction to enforce management, increase technical investment, and enhance technical content of the product, and as a result to consolidate the competitive power of energy-consuming products made in China on the international markets.

2.1.3 Meeting demand of world trade

After China's entrance into the WTO, the Chinese economy will transform into exported economy apace, the home enterprises will have more imports and exports. At the same time, based on consideration of energy saving and environment protection, all countries in the world, especially the developed countries, set some green trade barriers early or late and raised higher requirements on energy efficiency indexes toward the imported and exported goods. The world trade competition focuses on quality competition even more. To improve the energy efficiency criterion of products comes first to improve the quality competitive power. And only in this way, China can improve international competitive power of its products. Meanwhile, China should establish mutual admission with other countries to cut down trade barriers.

2.1.4 Satisfying requirement to protect the environment

During energy production, processing and utilization, pollution to the ecological environment inevitably is resulted, including air pollution, slag pollution and heat pollution. Among them, the most harmful factor to human being is resulted by air pollution. The environmental pollution in our country is typical energy consumed pollution. Refer to the survey done by related departments, in 1997, the total smoke and dust discharge in the whole country is 18.40 million tons and sulfur dioxide 23.70 million tons. Seventy and eighty five percent of them respectively are caused by energy consumption accordingly. Thirty percent of the carbon dioxide in the atmosphere is from electricity generation. And the electricity generation is also a major reason for greenhouse effect. The energy efficiency standard reduces environmental pollutant produced during energy production and utilization through improving the utilizing efficiency of energy.

2.2 Features of Chinese energy efficiency standards

2.2.1 Narrow coverage of energy efficiency standard

In 1995, China started to modify first group of energy efficiency standards and establish the energy efficiency standards for some new electrical home appliances and lighting products with the help of related governmental departments and some international associations, such as the International Energy Saving Research Institute, American Resource Foundation. However, up to the present, the energy efficiency standards only covers an even narrow range, mainly involving some home electric appliances, such as refrigerator, air conditioner, washing machine, and a few lighting devices and industrial equipment. The energy efficiency standards for widely-used energy-consuming appliances and equipment are not established yet.

2.2.2 Too low indexes of energy efficiency standards

For only part items of the compulsory energy efficiency standards are compulsory in our country at the present time, and there is an half year around from the standard establishment to its implementation, the manufacturers have relative short period of time to respond and improve their products to reach the standard, therefore, the supposed indexes of the energy efficiency standard is quite lower. The basic principle of energy efficiency limit is determined to eliminate 5 to 10% of bottom level products with high energy consumption, normally lower than the average energy efficiency standard in the near future market. It is mostly to restrict the production and sales of high-energy consumed products in current period. The energy saving evaluation factor which offering scientific foundation for energy saving product's attestation is relatively lower and not in favor of pushing and guiding the energy efficiency standard to improve in large scale.

2.2.3 Unideal implementation strength and effect of energy efficiency standards

Now, more than ten energy efficiency standards have been issued, but the implementation strength and effect are not ideal. On one side, it is due to the fact that no matched policy from the state (financial stimulation) is published on time, result the enterprises still carry out its own original production plan instead of being pushed forward toward the direction of technical innovation and improvement of energy efficiency. On the other side, it is due to the fact that the indexes required in the new energy efficiency standard are too low. The production efficiency in some big and middle-sized enterprises is higher than the energy efficiency index. In such cases, energy efficiency standards have no enough guiding function to the enterprises and influence the implementation effects of the whole energy efficiency standard system.

2.3 Gaps between developed countries and China

Reach energy efficiency standards raise higher requirements to the energy consumption based on the limited values of energy efficiency. It has a quite long period of time to put into practice, normally from three to five years. The energy efficiency limit defined in the standard is usually higher than the average present energy efficiency level in the market, even higher than the highest present energy efficiency level in the market. The energy efficiency standard in absolute majority countries such as United States, European Union and Japan belongs to leading ones. The energy efficiency level is determined based on developing trend of energy saving technology, through engineering economic analysis and energy saving modular arithmetic. It has already realized very excellent energy saving and environment protection effects.

2.4 Significance to implement reach energy efficiency standards

Positive functions of reach energy efficiency standards are showed in the following two aspects:

2.4.1 Emphasizing the targets of industry development

The reach energy efficiency standards are to raise even higher requirements to energy efficiency after the energy efficiency limit being defined by the standard to certain product. It affirms and expands the energy efficiency limit, at the same time, it promotes the enterprise to seek technical innovation and improve competitiveness.

2.4.2 Improving the guiding power of standards

The standards should make prospective forecast toward market and establish even higher target, only then it can realize rational guiding function toward the market. Because the energy efficiency limit and energy saving estimation value belongs to nowadays standard, so it can’t lead the enterprises to set its energy saving target for future development. The reach energy efficiency standard just covers this limitation. Based on elaborate survey and analysis to the whole industry, a limit beyond the capability of some enterprises should be established. As a result, it will lay a foundation for developing high energy saving and high efficient products designedly, driving to improve energy efficiency level of products as a whole, as well as reducing or eliminating unnecessary energy waste.

3 Calculation of energy saving potential

The model used for calculation of energy saving potential in this project was developed by the American Council of Energy-Efficient Economy (ACEEE). To quantify the energy saving after implementation of reach energy efficiency standards, benchmarks of product energy efficiency should be confirmed firstly. The reach energy efficiency standard means bring forward higher indexes on the basis of current energy efficiency standard and set up the developing aim for enterprises. Therefore, the benchmarks of reach energy efficiency standards are the minimum allowable of current energy efficiency standards for corresponding products.

Model analysis of energy saving potential can be divided into energy saving analysis, environmental analysis, commercial analysis and peak demand analysis. Project forecast period is 12 years (2008~2020). The analysis process has been summarized as follows:

3.1 Energy saving analysis

Energy saving analysis is the most important and basic stage of the model analysis of energy saving potential. Collecting a series of products performance and operation data such as annual output, average driving power and average annual operation time are necessary for quantifying the energy reduction due to the implementation of reach energy efficiency standards. For the products of pump and fan, formula (1) for calculation of annual energy saving is given as:

$$E_{s0} = P_{av} \times T_{av} \times (\frac{1}{\eta_2} - \frac{1}{\eta_1}) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

In which: E_{s0} ---- annual energy saving per unit, kWh/unit;

P_{av} ---- average driving power, kW;

T_{av} ---- average annual operation time, hour；

η_1 ---- reach energy efficiency, %;

η_2 ---- benchmark of energy efficiency, %.

Formula (2) for calculation of annual energy consumption for pump and fan is given as:

$$E_{c0} = \frac{P_{av} \times T_{av}}{\eta_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

In which：

E_{c0} ---- annual energy consumption, kWh/unit·year.

Formula (3) for calculation of annual energy saving for air compressor is given as:

$$E_{s0} = (\xi_1 - \xi_2) \times Q \times T_{av} \quad \text{...........} \ (3)$$

In which:

ξ_1 ---- minimum allowable of specific power in GB19153, kW/m^3 • min;

ξ_2 ---- evaluating value of specific power in GB19153, kW/m^3 • min;

Q ---- air compressor flowrate capacity, m^3/min.

Formula (4) for calculation of annual energy consumption for air compressor is given as:

$$E_{c0} = \xi_1 \times Q \times T_{av} \quad \text{...........} \ (4)$$

During the calculation of product annual energy saving, we did not simply use annual energy saving of high efficiency product per unit to multiply the market inventory of the product. The new high efficiency products can not be sold completely at the beginning of each year, but are continuously sold throughout the year. Moreover, high efficient products sold in different month will contribute different energy saving amount in the first year. Therefore, product annual energy saving amount can be processed as formula (5):

$$E_{sn} = E_{s0} \times (I_n - 0.5 S_n) \quad \text{...........} \ (5)$$

In which:

E_{sn} ---- total energy saving amount of high efficient products in nth year, kWh;

I_n ---- market inventory of high efficient products in nth year, unit;

S_n ---- number of product sold in nth year, unit.

Market inventory is a very important conception in the model analysis of energy saving. It means the amount of high energy efficiency products at sometime in the market and the value of it depends on product output, sales coefficient and product life. The detailed calculation and formula will be discussed in chapter 4.

The values of Heat Rate and T&D Losses need to be determined for transforming the energy saving unit of kWh into the one of MMTce. The transforming formula has been given as follows:

$$E_{sn}{}' = E_{sn} \times \frac{HR_n}{(1 - TDL)} \quad \text{...........} \ (6)$$

Where:

E_{sn}' ---- total energy saving of high efficiency product of nth year, MMTce;

HR_n ---- Heat Rate of nth year, gce/kWh;

TDL ---- T&D Losses, %.

3.2 Environment analysis

Because coal is the absolute primary resource in Chinese energy consumption structure and most power stations belong to firepower stations, which always discharge a great number of CO_2, SO_2, NO_x , PM_{10} and other poisonous gases and make serious environmental pollution during the combustion of fossil fuels such as coal. Reach energy efficiency standards can improve product energy efficiency and reduce the energy consumption, particularly the power consumption, so the environmental pollutants caused by the combustion of the fossil fuel in power station can be reduce significantly.

Formula (9) ~ (12) for calculation of emission reductions of main atmosphere pollutants of CO_2, SO_2, NO_x , PM_{10} caused by the implementation of reach energy efficiency standard are given as:

$$C_n = \frac{E_{An}}{(1-TDL)} \times C_c \qquad \text{............} \; (7)$$

$$N_n = \frac{E_{An}}{(1-TDL)} \times N_c \qquad \text{...........} \; (8)$$

$$S_n = \frac{E_{An}}{(1-TDL)} \times S_c \qquad \text{...........} \; (9)$$

$$PM_n = \frac{E_{An}}{(1-TDL)} \times PM_c \qquad \text{.......} \; (10)$$

Where:

C_n ---- accumulative pollutant reduction of carbon of nth year, M ton;

N_n ---- accumulative pollutant reduction of nitrogen oxide of nth year, M ton;

S_n ---- accumulative pollutant reduction of sulfur dioxide of nth year, M ton;

PM_n ---- accumulative pollutant reduction of particulates of nth year, M ton;

E_{An} ---- accumulative product energy saving amount of nth year, TWh;

C_c ---- emission factor of carbon for electricity, kg/kWh;

N_c ---- emission factor of nitrogen oxide for electricity, kg/kWh;

S_c ---- emission factor of sulfur dioxide for electricity, kg/kWh;

PM_c ---- emission factor of particulates for electricity, kg/kWh;

3.3 Economic analysis

Improving product energy efficiency will result in increased product manufacturing cost and sales price. However, reduction of energy consumption due to high energy efficiency product employment will cut the charge of energy consumption without doubt. Therefore, it is necessary to introduce the conception of Life Cycle Cost and Payback Time to quantify the cost-benefit problem of the project.

3.3.1 Life cycle cost

Product life cycle cost normally can be divided into the manufacture cost, which includes research, design, manufacturing, experiment and sales cost, and the operation cost including operation, maintenance, repair, insurance, etc. that the operation cost should take discount rate into account. The summation of product manufacture and operation cost is just the product life cycle cost.

Generally, product manufacture cost can be represented by the commodity value in product sales, namely the product price. So it can be considered as an integrated variable. However, operation cost usually has more maneuverability and people always adjust variables included in the operation cost to reduce the product life cycle cost.

We analyze both sides of the product life cycle cost. Change of product manufacture cost caused by any elements can be reflected by product sales price. Operation cost is a little more complex and can be separated into two parts: one is product energy consumption cost; the other is cost of maintain, repair and etc. We introduce an integrated parameter (ξ) to stand for the cost change of product maintain, repair and etc. after the utilization of high efficiency product. Generally, application of more advanced technologies will result in longer maintain/repair cycle and more maintain/repair cost. According to the data and information we have got currently, it is unpractical to make an accurate calculation to the parameter. To simplify the analysis model, we assume there is no change between original and high efficiency products in the cost of product maintain and repair. Therefore, the product operation cost is equal to the product energy consumption cost. Formula (11) for calculation of product LCC is given as:

$$LCC = MC + \sum_{n=1}^{N} \frac{OC_n}{(1+r)^n} \quad \text{…………} \ (11)$$

In which:

LCC ---- product life cycle cost, yuan;

MC ---- product sales price (manufacture cost), yuan;

OCn---- product energy consumption cost of n^{th} year (operation cost), yuan;

r ---- discount rate, %;

n = 1, 2, 3,……;

N ---- years to be calculated.

3.3.2 Payback time

Payback time refers to the period of time over which the increased purchase cost of an energy-efficient product is offset by reduced operating cost. It's an important index to evaluate the economic effect of energy conservation. Longer of the payback time means better of the economic effect. The payback time can be obtained through formula (12):

$$\Delta MC_0 - \sum_{n=1}^{PAY} \frac{\Delta OC_n}{(1+r)^n} \leq 0 \quad \text{………… (12)}$$

The formula (12) clearly discloses the relations between cost and benefit. The economic benefit of high efficiency products has been reflected through two opposite aspects, cost increase and energy saving. To simplify the calculation, we assume the product energy efficiency improvement is linear with product sale price increase. The calculation is denoted as follows:

$$\Delta MC_0 = \kappa \times \frac{\Delta \eta}{\eta_2} \times MC_0 \quad \text{………… (13)}$$

In which:

ΔMC_0 ---- increased investment cost of each high efficiency product, yuan/unit;

k ---- ratio (empirical value);

$\triangle\eta$ ---- energy efficiency increase capacity of each product, %;

MC_0 ---- average sales price of each product, yuan/unit.

On another hand, high efficiency products will save a large number of electricity consumption during the subsequent operation. Introducing the forecasted values of national average electricity price for common industry, corresponding operation cost reduction in each year can be calculated through the formula (14):

$$\Delta OC_n = P_{en} \times E_{s0} \quad \text{………… (14)}$$

In which:

ΔOC_n ---- operation cost reduction of each product in n^{th} year, yuan/unit;

P_{en} ---- national average electricity price of common industry in nth year, yuan/kWh.

If the discount rate and electricity increase will not be taken into account, the calculation formula can be simplified into as follows:

$$PAY \approx \frac{\Delta MC_0}{\Delta OC_0} \quad \text{…………} (15)$$

In which:

ΔOC_0 ---- operation cost reduction of each product, yuan/unit.

Besides payback time, other economic parameters such as net present value (NPV), net benefit (NB) and ratio of benefit-cost (BCR) can also be used to evaluate the economic benefit of some project. Those parameters can be calculated through formula (16) ~ (20) as follows:

$$NPV = \sum_{i=1}^{m} \frac{V_i}{(1+r)^i} \quad \text{…………} (16)$$

In which:

NPV ---- net present value, million yuan;

V_i ---- ΔMC_T or ΔOC_T, million yuan.

$$\Delta MC_T = \Delta MC_0 \times S_n \quad \text{…………} (17)$$

In which:

ΔMC_T ---- total increased cost of high efficiency products in n^{th} year, million yuan.

$$\Delta OC_T = P_{en} \times E_{sn} \quad \text{…..………} (18)$$

In which:

ΔOC_T ---- total operation cost reduction of high efficiency products in n^{th} year, million yuan.

$$NB = NPV_{\Delta MC_T} - NPV_{\Delta OC_T} \quad \text{...…… } (19)$$

In which:

NB ---- net benefit of the project, million yuan;

$NPV_{\Delta MCT}$ ---- net present value of increased investment cost of the project, million yuan;

$NPV_{\Delta OCT}$ ---- net present value of reduced operation cost of the project, million yuan.

$$BCR = \frac{NPV_{\Delta OC_T}}{NPV_{\Delta MC_T}} \quad \text{.....................…} (20)$$

In which:

BCR ---- benefit-cost ratio of the project.

3.4 Peak-hours demand analysis

Reduction of electricity consumption alleviates the power supply burden of power net during the peak hours, improves the operation reliability of power system and also reduces the requirement of new power station. Amount of peak demand reduction can be calculated through formula (21):

$$R_n = E_{sn} \times \mu \times \frac{\theta}{1 - TDL} \quad \text{.....................} \ (21)$$

In which:

R_n ---- reduction of peak-hours demand, GW;

θ ---- reserve margin;

μ ---- peak factor, kW/kWh.

4 Energy saving potential of main industrial energy-consuming products

According to the statistics made by the State Statistical Bureau on June 2004 to 2598 enterprises within the general machinery industry, there are 744 pump manufacturers, 277 fan manufacturers and 168 air compressor manufacturers among those enterprises. It is roughly estimated that the total industrial pump output in 2004 was 3.29 millions sets,[2] fan output over 1 millions sets,[3] air compressor 2.30 millions sets. For simplifying the research, the report assumed that the statistic data in the China Machinery Industry Annual (2002) could represent the proportion among pump varieties in home market and various types of fans. Pumps, fans and air compressors are main industrial energy-consuming equipment with accumulated annual power consumption up to 40% of total power supply in our country. The design efficiency of majority products still have large gap with advanced international level, resulting irrational operation and great resource waste. So, it is very important to improve the energy efficiency level of pumps, fans and air compressors for enterprises to enhance competitiveness in international market.

4.1 Pumps

4.1.1 Product status

(1) Basic description

① Definition

Pump is a machine to transform mechanical energy of motive power into hydraulic energy. The motive power machine (electromotor, diesel engine, etc.) drive impeller to rotate through pump shaft and act on fluid to make its energy (including potential energy, pressure energy and kinetic energy) increased, consequently to feed the fluid to high point o need for pressure.

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[2] The annual pump output estimation of large scaled enterprises all over China in 2001 was based on annual output of the Pump Manufacturers Association which has 133 members. It was on the assumption that the products were generally made by the Pump Association members and scale enterprises not included in the Association, and the average output of those scale enterprises not included in the Association was 30% of the Association. Based on explanation above, the total pump output in 2001 was estimated. And it is assumed that the average annual increase ratio from 2001 to 2004 was 15%.

[3] Based on annual fan output estimation of Fan Manufacturers Association who has 80 members to estimate the annual fan output by scale enterprises all over China in 2001 is as same as pumps. It is assumed that the average output of those scale enterprises not included in the Association was 40% of the Association and the average annual increase ratio from 2001 to 2004 was 30%.

② Classification

At present, there are totally 1288 types of pump products within 87 series in our country. All products can be divided into 2200 kinds and 35 styles, as well as numerous sizes and varieties. Except the pumps used in nuclear industry, our country can manufacture various large-sized equipment set, such as special pump used for oil refining plant with annual output of 2.50 million tons, electricity generator set over 600,000 kW, and equipment to produce 300,000 tons ethylene, large scale synthetic ammonia carbamide and compound fertilizer.

The pump can be divided into the following styles according to working principle and structure:

Blade pump: driven by the rotation of blade to transfer energy to fluid and increase the fluid energy.

Displacement pump: driven by displacement change principle, namely to increase or decrease working displacement through periodic displacement of object and transfer the energy as a result.

Table 4-1: Product Categories of Pump

<table>
<tr><td rowspan="7">Pump</td><td rowspan="4">Blade Pump</td><td>Centrifugal Pump</td><td>Single-stage, multi-stage, single-suction, double-suction, etc.</td></tr>
<tr><td>Axial Pump</td><td>Fixed Blade Pump (single-stage, multi-stage), Movable Blade Pump</td></tr>
<tr><td>Mixed Pump</td><td></td></tr>
<tr><td>Vortex pump</td><td>Single-stage Pump, Multi-stage Pump, Centrifugal Vortex Pump</td></tr>
<tr><td rowspan="2">Displacement Pump</td><td>Reciprocating Pump</td><td>Electric Pump(such as Piston Pump, Plunger Pump, Diaphragm Pump), Steam Pump</td></tr>
<tr><td>Rotary Pump</td><td>Gear Pump, Screw Pump and etc.</td></tr>
<tr><td>Other Types</td><td colspan="2">Jet Pump, Electromagnetism Pump and etc.</td></tr>
</table>

Source: *Manual of Industry Pumps*

③ Major parameters and features

For there are too many types of pumps, its major parameters and features are different from each other. The following table is introduced to give a general description of application and features of major pump types in order to make it simple and clear to readers.

Table 4-2: Characteristics of Pumps

Index		Laminar pumps			Displacement pumps	
		Centrifugal	Axial	Vortex	Reciprocating	Rotary
Flowrate	Uniformity	Very Uniform			Non-uniform	Uniform
	Stability	Non-stable			Stable	
	Scope (m^3/h)	1.6~30000	150~245000	0.4~10	0~600	1~600
Head	Features	Only one specific head can be reached for a flowrate			Different heads can be reached for a flowrate	
	Scope	10~2600m	2~20m	8~150m	0.2~100MPa	0.2~60MPa
efficiency	Features	From the zenith of efficiency, farther departure, lower efficiency			Little drop of efficiency in the case of high head	Much drop of efficiency in the case of high head
	Scope(zenith)	0.5~0.8	0.7~0.9	0.25~0.5	0.7~0.85	0.6~0.8
Structure features		Simple structure, low manufacturing cost, small, light and convenient for installing and examination			Intricate structure, high manufacturing cost, big and obvious vibration	Same to centrifugal pumps

Source: *Manual of Industry Pumps*

④ Characteristic curve

The curve to represent correlations between major parameters is named performance curve or characteristic curve. In fact, the characteristic curve of pumps is external form of expression of internal movement of fluid in the pump. It is learned from actual measurement, different type of pump has different characteristic curve resulted from different structure and working principle.

As to the most widely-used centrifugal pumps, its characteristic curve includes flux-head curve (H-Q), flux-efficiency curve (η-Q), flux-power curve (N-Q), flux-NPSHr curve (NPSHr-Q). The function of characteristic curve is: any flux point has a group of head, power, efficiency and NPSHr value shown on the curve corresponding to this point. This group of parameters is called working condition, simply speaking operation mode or mode point. The highest efficiency point of centrifugal pump is called best mode point. It is normally the design mode point. The rating parameters of normal centrifugal pump refers that the design mode point is superposed or very close to the best mode point. In practice, to run the pump within its efficiency range may save energy as well as ensure well-balanced operation. So it is very important to understand the performance parameters of centrifugal pump.

See the following figure for characteristic curve of centrifugal pump made by home manufacturers:

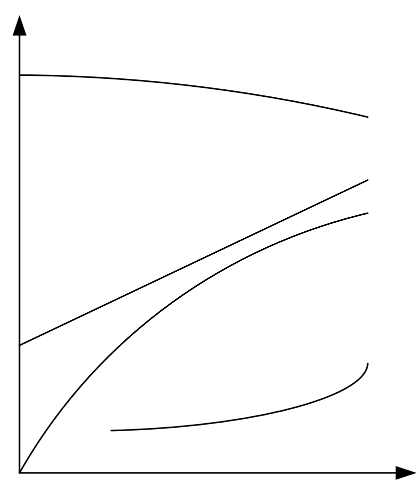

Figure 4-1: Typical characteristic curve of centrifugal pumps

(2) Market analysis

① General introduction

China is one of the largest pump manufacturing countries in the present world. In 2003, the apparent demand for pumps in Chinese market was 25.35 billion Yuan. It is estimated that the apparent demand for pump in 2005 will be 30.5 billion Yuan. At present, there are over 5000 pump manufacturers in our country. Most of them are small-scaled enterprises. It is indicated by the statistic made by the State Statistic Bureau in 2003 there are 696 scale enterprises in China, among them, 14 in large scale, 65 in middle scale and 617 small-sized enterprises. The sales income of top 30 enterprises within home pump industry was 6.21 billion Yuan, account for 30.31% of sales income of the industry. The enterprise concentricity is a little bit higher than average machinery industry. It is estimated by experts that the inventory of pump in our country is 20 million sets, annual output over 2 million sets, and members of the China General Machinery Pumps Industry Association account for majority shares (about 50.42%).

② Product efficiency

The product efficiency ranges are different because there is various pump products in Chinese market. The products made by some middle and large-scale state-owned enterprises, large-scale collective, nongovernmental and private-owned enterprises enjoy high efficiency for their high production technology, advanced and complete equipment. However, the products made by small nongovernmental and private-owned enterprises have quite lower efficiency because of their simple equipment and backward technology. Generally speaking, the pump product efficiency as a whole in our market is rather lower. The reasons for such fact are represented in the following aspects:

- Low reliability of system, low quality of production
- The State lacks measures to intervene other than issuing license to manufacturers within agricultural machinery and chemical industry. The State has no measures taken to other industries. So too many manufacturers (more than 5000 all over the country) with different scale, various products and uneven quality existing in China, resulting in low efficiency all around.
- The users are not clear with parameter selection when purchasing, or keep the product operation at wrong mode point instead of rating mode point for long time in practice, consequently get lower running efficiency.
- The non-standard products made by some manufacturer according to customers' requirements have lower efficiency.
- The users lack efficiency acknowledgement and seldom care about the efficiency.

③ Output

According to the statistics made by the China General Machinery Industry to its 133 members, in 2001 the output of pump Industry was 1,090,672 sets, 5.9% higher than last year.

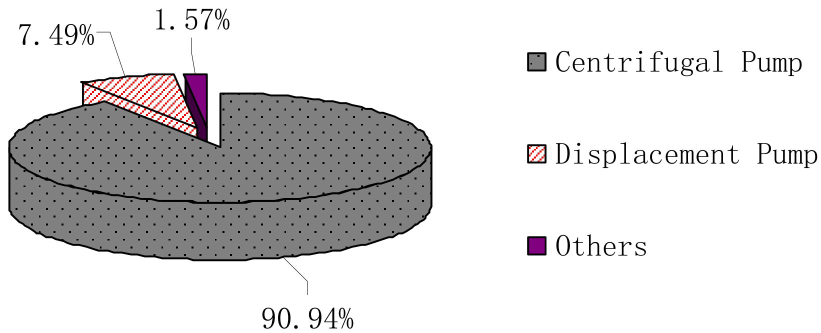

Figure 4-2: Market Share of Different Pumps in 2001

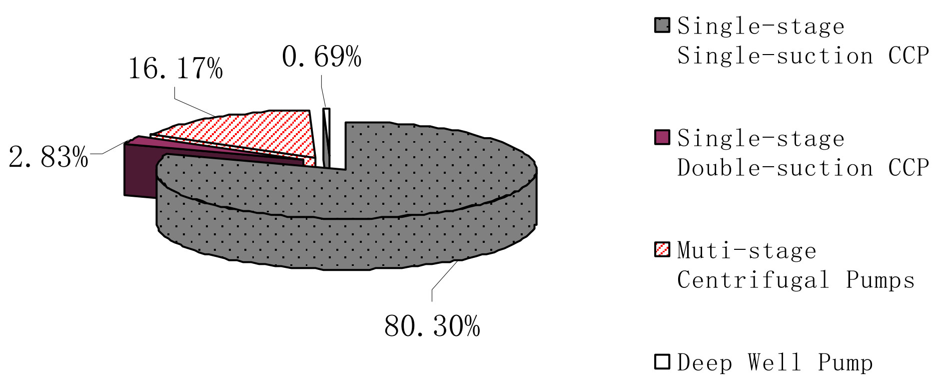

Figure 4-3: 2001 Output Proportion of Centrifugal Pumps

Source: China Machinery Industry Yearbook 2002

Analyzing the statistic data of the year 2002 for pump products in China Machinery Industry Annual (see Figures 4-2 and 4-3), although there is variety of pump products in Chinese market presently, the centrifugal pump plays a dominant position, accounting for 91%. Another 7% is nonstandard products specially made according to customer's requirements and other types named by the enterprisers themselves. From analyzing different types of products within centrifugal pumps, it was found that clean water centrifugal pumps account for 49% of total pump output in 2001 and 54% to total centrifugal pump output. So, to establish reach energy efficiency standard for clean water centrifugal pump first of all has certain scientific bases.

4.1.2 Energy consumption analysis

(1) Criterion data

① Average product's life

In order to obtain precise data reflecting actual home market, the project team entrusted Beijing Up-Point Consulting Co., Ltd, an authentic consultant in our country, started a special survey and study from October 8, 2004 on improving product's efficiency to the manufacturers of three types of general machinery equipment (clean water centrifugal pumps, ventilation fans, displacement air compressors) all over China and ended in November 2004, lasting more than one month. Limited by the expenses, the survey focused on some middle and large-scale enterprises to determine the nature. The middle and large-scale enterprises accounted for two thirds of total survey objects. Minority work was to determine the amounts, mainly including normal product's life, average product's driving power, and present product's marketing price.

Synthesizing the estimating data from various manufacturers, it was found that the normal service life of small-sized clean water centrifugal pumps below 10 kW was 8.5 years, lower than the product above 10 kW. The average service life of clean water centrifugal pumps over 100 kW even reached 10.6 years.

- 0-10 kW，average life 8.5 years;
- 11-50 kW，average life 9.8 years;
- 51-100 kW，average life 9.6 years;
- ＞100 kW，average life 10.6 years.

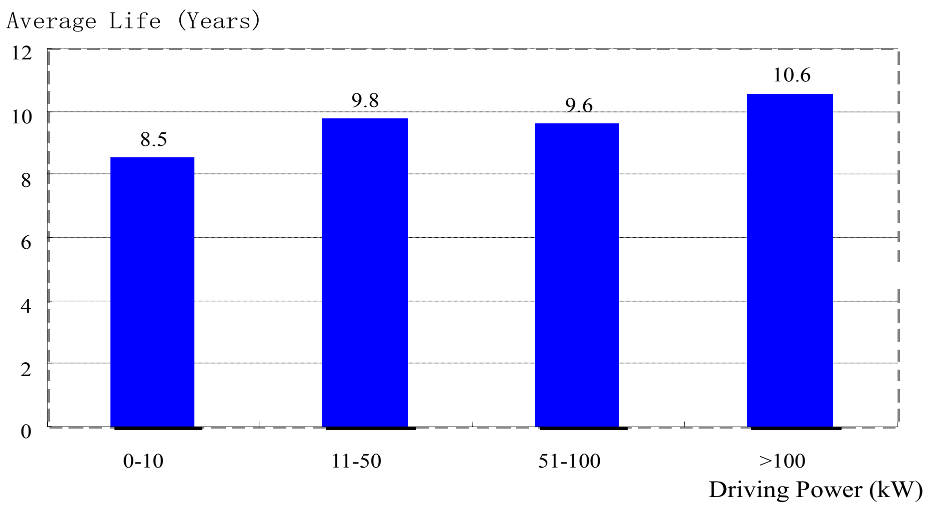

Figure 4-4: Average Life for Different CCP

Source: Market Survey Report for CCP

We could learn from the survey result that the average service life of clean water centrifugal pumps is improved as the driving power being increased. The normal service life of clean water centrifugal pumps with 10-100 kW is close to 10 years. For ease calculation, we might take ten years as the average service life of the survey object, namely the clean water centrifugal pumps.

② Output and market inventory

The method to estimate annual output of clean water centrifugal pumps was as following:

Based on the statistic data made to 133 backbone enterprisers within pump Industry in 1999, 2000 and 2001 by the China Machinery Industry Annual, and the output of clean water centrifugal pump in 2002 and 2003 referring to the increase speed published by the China Machinery Industry Annual 2004, these five years data was taken as basic point, the average annual increase rate was calculated based on expectation of future output trend of clean water centrifugal pump with logarithm regression analysis method. See Figure 4-5 for estimated results:

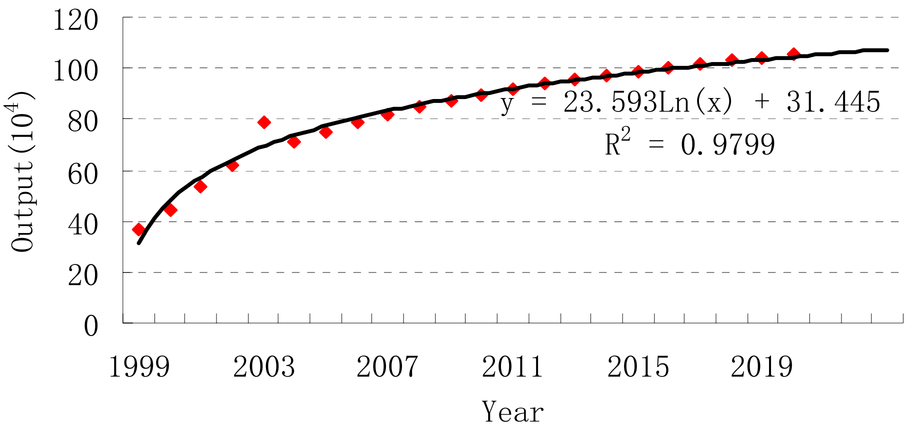

Figure 4-5: Output Forecast of CCP

The average annual increase rate of output of clean water centrifugal pump was calculated 6.64% based on expectation result.

The average sales index (ω) of clean water centrifugal pump was calculated in accordance with the ratio between pump sale and output in 1999, 2000 and 2001. The sale of clean water centrifugal pump for present year is obtained by multiply the index by the output in this year. Formula (18) for calculation of the sale amount is given as:

$$S_n' = O_n' * \omega \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (22)$$

In which:

S_n'---- sale amount of CCP from pump association in n^{th} year, unit;

O_n'---- output of CCP form pump association in n^{th} year, unit.

One point must be paid attention to is that the output of clean water centrifugal pump here referred was the output of the members of China General Machinery Pump Industry Association. Though it accounted for quite big proportion (about 50.24%) compared with total output of the country, it could not be taken to calculate energy saving quantity representing for annual pump output of the country. Here, the total annual pump output of scale enterprises was taken to represent total pump output in the country. In 2001, there were 569 pump manufacturers with certain scale all over the country, 133 enterprises were members of the Pump Industry Association. After discussion among experts and associations time and again, it was assumed that the output of non-association enterprises was 30% of those members. Then, the calculation formula of total sale of clean water centrifugal pump all over China is given as follows:

$$S_n = \frac{S_n'}{133} \times 30\% \times (569 - 133) + S_n' \text{ ……… } (23)$$

For the reach energy efficiency standard will be implemented three to five years later, we can consider the year 2008 as the potent implement year for the energy efficiency standard of clean water centrifugal pump. Therefore, national market inventory of CCP can be forecasted using following formula:

$$I_n = \sum_{i=\text{effective year}}^{n} S_i \text{ ………………… } (24)$$

After 2017, calculation of national market inventory of CCP is given as formula (25) :

$$I_n = \sum_{i=n-9}^{n} S_i \text{ ……………… } (25)$$

Forecast result of national market inventory of CCP from 2008 to 2020 is given by Figure 4-6:

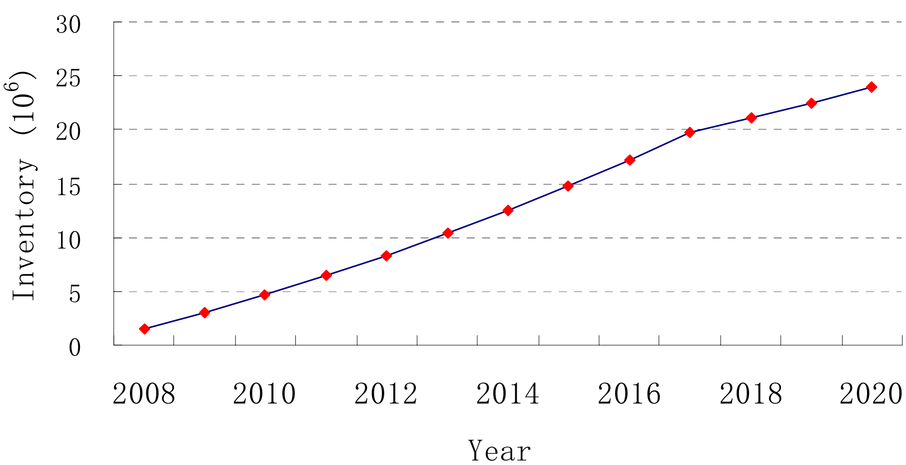

Figure 4-6: Inventory Forecast of CCP

We can see from the Figure 4-6 that the market inventory for clean water centrifugal pumps will decline in evidence from the year 2017 because the normal service life of home product is 10 years.

③ Average driving power

In order to calculate the potential energy saving of reach energy efficiency standard, the average driving power of clean water centrifugal pump must be determined firstly. Limited by the survey expense, the average driving power in the survey questionnaire was just an estimated value done by production and technical department of the enterprises. It could not be used in the model calculation. However, it could also reflect the development trend of driving power in the market. See Figure 4-7:

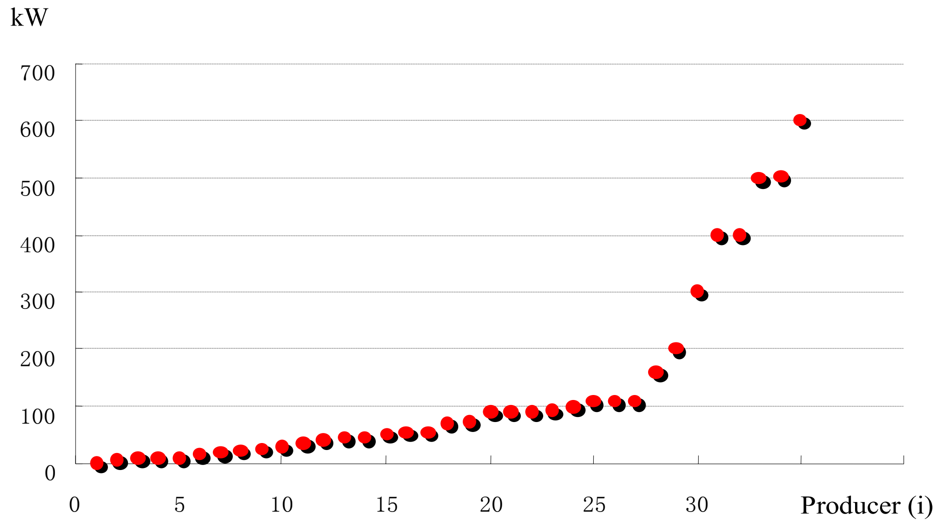

Figure 4-7: Driving Power Trend of CCP

Source: Market Survey Report for CCP

We can see from the figure above, the driving power of most clean water centrifugal pumps is below 100 kW. Among the investigated enterprises, only 30% estimated its average driving power above 100 kW. In order to quantify the average driving power, we take the data of large-scale survey project done to electromotor this year. Although the product ranges reflected by these two groups of data are not exactly same, electromotor corresponds to all kinds of industrial pump, this project just consider the clean water centrifugal pump. However, we can take this result to calculate the average driving power of clean water centrifugal pump for the moment because this product enjoys majority of total market share. See Figure 4-8 for driving power distribution of CCP:

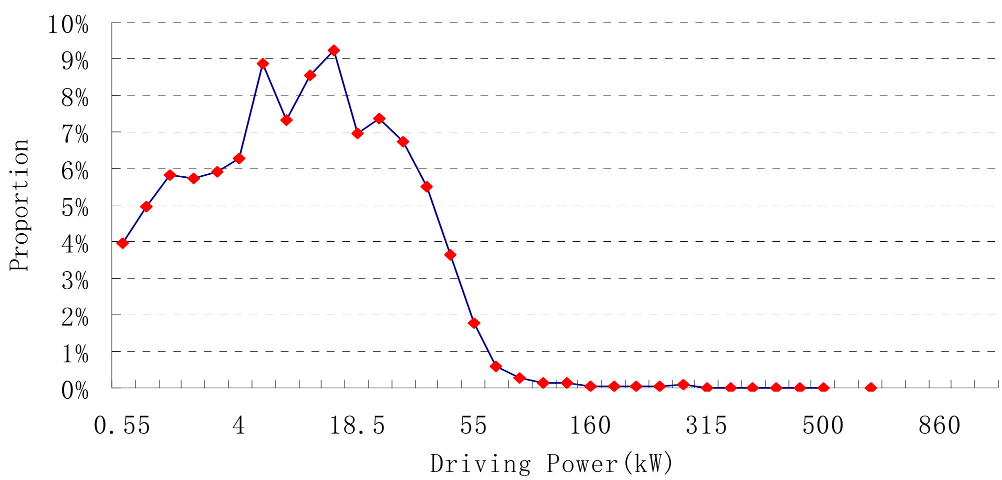

Figure 4-8: Driving Power Distribution of CCP

Source: Market Survey Report of Medium and Small Three Phase Asynchronism Electric Motor

On the assumption that the driving power condition will hold the line with the future development of the pump industry, the average driving power of clean water centrifugal pump in home market can be calculated 15.62 kW based on prospected market inventory.

④ Average operation time

According to the data reflected by the survey company, 24 hours a day is divided into eight time periods. The utilizing rate in different time period was investigated. The result is shown in Table 4-3.

Table 4-3: Operation Time Stat. of CCP

Sequence Number(i)	1	2	3	4	5	6	7	8
Time Scale	0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-24
Frequency(ψ_i)	0.1	0.2	0.5	0.8	0.8	0.8	0.5	0.2
Average Annual Operation Time(T_{av})	$T_{av}=\sum_{i=1}^{8}\psi_i\times\frac{24}{8}\times 365=4270.5$ hours/year							

Source: Market Survey Report of Medium and Small Three-phase Asynchronism Electric Motors

The average running time of 11.7 hours per day can be calculated from statistic data in Table 4-3. Considering the study object is industry area with relative high running time, we can assume a compound parameter ϕ to reflect the factors may influence annual electricity consumption, such as the proportion of pump product used in industry area and running rate. If we assume the compound parameter ϕ=0.4, we can get the equivalent annual running time of clean water centrifugal pump is 1708.2 hours.

(2) Energy consumption estimation

At present, the national standard *Limited values of energy efficiency and evaluating values of energy conservation of centrifugal pump for fresh water*, is already in publicizing period. This national standard will be regarded as principle to calculate benchmark energy consumption amount and forecast amount. Because clean water centrifugal pumps consists many different styles, such as single-stage, multi-stage, single-suction, double-suction clean water centrifugal pumps, at the same time, the limited values of energy efficiency and evaluating values of energy conservation depend on flux and ratio rotate speed of the clean water centrifugal pump, so we take one type of pump with a certain group parameter environment to calculate its basic energy consumption amount and forecast amount to make the issue clear through simple calculation.

The selected samples are single-stage, single-suction clean water centrifugal pumps with a flux no more than 300m^3/h, ratio rotation speed less than 120 or more than 210. In accordance with Limited values of energy efficiency and evaluating values of energy conservation of centrifugal pump for fresh water, based on conditions above, we can get efficiency modification value △η=3%, design point efficiency 77.3%, limited value of energy efficiency 74,3%, evaluating value of energy conservation 79.3%, so we can calculate annual electricity consumption of clean water centrifugal pump for single unit E_c=35912 kWh. Referring to the prospected result of inventory of clean water centrifugal pumps in the basic data, we can get the forecast value of future energy consumption under the condition that the clean water centrifugal pump maintain present efficiency level. See Figure 4-9:

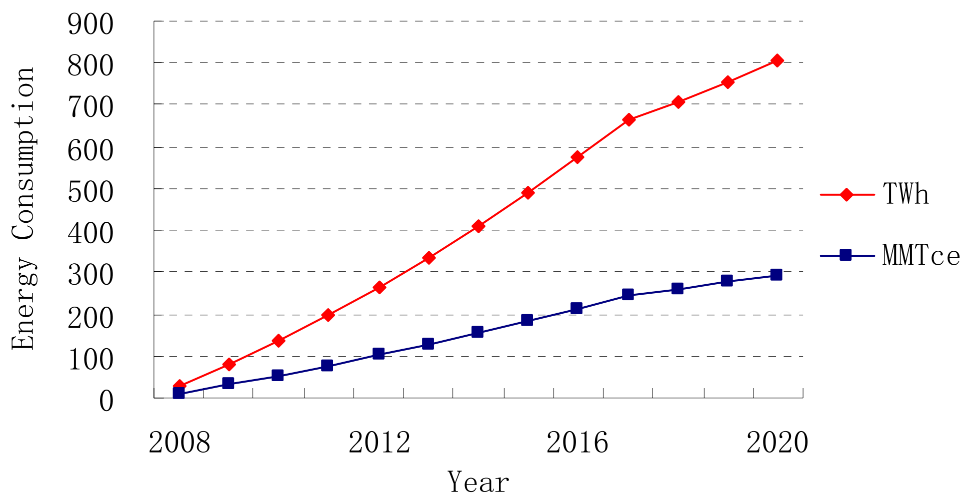

Figure 4-9: Energy Consumption Forecast of CCP

We can see from the figure, if clean water centrifugal pumps are maintained the present efficiency, the energy to be consumed is a gigantic number. It is estimated that electricity consumption in 2010 will be 137.94 TWh, amount to about 53.654 million tons standard coal of non-recycled resource. The electricity consumption will be increased to 805.89 TWh dramatically until 2020, amount to about 292 million tons standard coal of non-recycled resource.

4.1.3 Technical resolution to save energy

(1) CFD current field analysis software

The fluid flowing within pumps is highly three-dimensional, typically including vortex, turbulence, non-stability, as well as interaction between static parts and rotating parts. For the current field movement is most complicated, even perfect hydrodynamics can't explain it. As the computer technology becomes matured day after day, people never ceased attempting to use the mighty calculation capability of computer to simulate actual current field changes, by that means to provide strong support to the improvement of pump design efficiency. The CFD make designers feel convenient obviously through offering them with complete fluxion data and better fluid fluxion image. This technique possessed many advantages: optimizing performance under various running conditions; reducing water source loss; lowering vibration and noise; cutting down repeated cycling and fluxion separation; testing design effect before expensive experiment; uppermost shortening time needed for new design development and decreasing risk; improving reliability and durability, as well as lowering down expenses for maintenance.

(2) Adoption of advanced experimental technology

The research to pump design technology is long-standing in western developed countries. The research to the value of unfixed fluxion within fluid engine and related experiment study are domestic and abroad hotspot presently. Especially as the computer and laser measure technology develop, the research on this topic penetrates more deeply. The Particle Image Veloci-meter (PIV), Hot-Wire Anemometry (HWA), Laser Doppler Anemometer (LDV) and data acquisition system are used to measure and analyze the unfixed three-dimensional flow physics values and onflow parameter during flowing process, explore fluxion law and validate numerical calculation. The fully adoption of these experiment technologies is of great benefit to design efficiency improvement of clean water centrifugal pump.

(3) Considering the features of pump self

The pump design should consider the features of pump self. Usually the following measures are taken to improve the design efficiency of products:

- Adopt special bearing and sealing technology to minimize mechanical loss;
- Adopt special connector gap or shape to minimize internal leakage;
- Reduce roughness of wet surface material within the body
- Adopt flow guiding blade or division blade
- Adopt special design which reduce water loss of pump products

(4) Technical personnel's suggestion

At the present time, there are lots of technologies in favor of improving efficiency of general equipment. The manufacturers of clean water centrifugal pump recommend following technologies.

Table 4-4: Measures to Improve Efficiency of CCP

1	Adopting CFD to optimize products design
2	Adopting SFD nozzle
3	Improving mechanism seal
4	Improving manufacturing skill
5	Improving design and foundry skill of pump impeller
6	Advanced dope
7	Introducing advanced sample-machine from oversea countries
8	Introducing new product model from Germany and America

4.1.4 Comparison between domestic and abroad energy efficiency standards

(1) China current energy efficiency standards and other relative standards

- Limited values of energy efficiency and evaluating values of energy conservation of centrifugal pump for fresh water (publicizing period)
- GB/T 3216 Centrifugal pump, mixed pump, axial pump and vortex pump testing approaches
- GB/T 5657 Centrifugal pump technology requirement（III type）（eqv ISO 9908:1993）
- GB/T 7021 Glossary of centrifugal pump
- GB/T 13006 Centrifugal pump, axial pump and mixed pump NPSHr
- JB/T 443 Centrifugal Deep-well Pump Technology Requirement

(2) abroad current energy efficiency standards and other relative standards

Generally speaking, there are very limited energy efficiency standards overseas about fans, pumps and air compressors used in industrial area for the moment. Only a few countries (See table 4-5) implement mandatory energy efficiency standards and related energy efficiency identification system to pump product. On the other hand, the test and evaluation procedures are widely self-imposed recognized among the national industry associations and international standardization organizations. Those widely recognized test procedures lay a foundation for establishment of energy efficiency standards and identification system in the future.

Table 4-5: International Pumps Mandatory Efficiency Performance and Labeling Standards

Economy	Equipment Sub-Type	MEPS	Labeling	National Test STD	Reference Testing Standard
Chile	Residential Centrifugal Pumps		**U**	NCh 2648:2002	NOM-004-ENER-1995
	Deep Well Pumps		**U**	NCh 2699:2002	NOM-006-ENER-1995
	Submersible Pumps		**U**	NCh 2700:2002	NOM-010-ENER-1996
Mexico	Residential Centrifugal Pumps	**Ym**	**Ym**	NOM-004-ENER-1995	ISO 3555 Class B
	Deep Well Pumps	**Ym**		NOM-006-ENER-1995	
	Submersible Pumps	**Ym**		NOM-010-ENER-1996	ISO 3555 Class B
	Vertical Pumps	**Ym**		NOM-001-ENER-2000	ISO 3555 Class B
Iran	Industrial Centrifugal Pumps		**Ym**		

MEPS=Mandatory Efficiency Performance Standard, Yv=Yes, voluntary;

Ym=Yes, mandatory; U=under consideration; N=none

Source: CLASP 2004

The design efficiency of pump product will vary because of different design method, material, etc. At present, the average design efficiency of pump is 75% and left behind by nearly 5% by similar products in advanced countries.

Figure 4-10, the National Standard on clean water centrifugal pump design and application issued in 2000 by American government, gave detail reference index for available best efficiency level in normal condition.

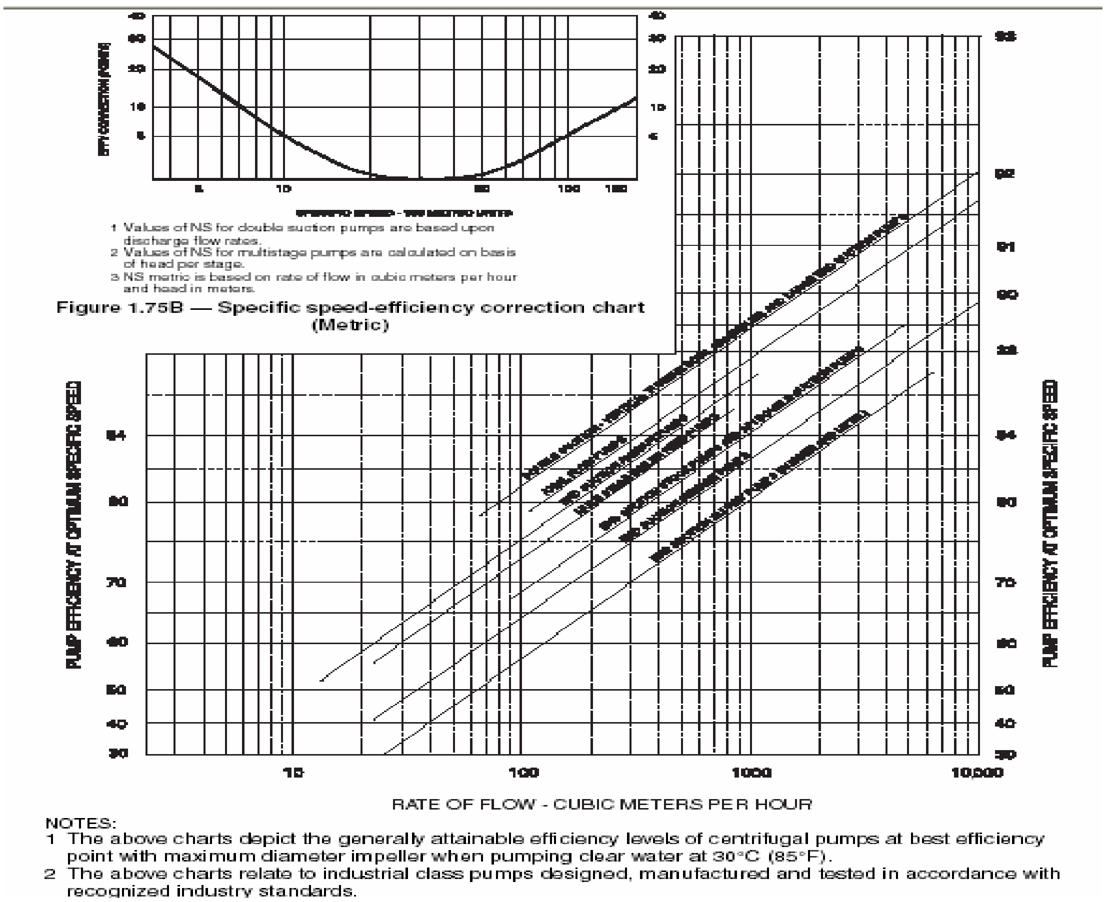

Figure 4-10: Generally Attainable Efficiency of CCP

Source：ANSI/HI1.3-2000

4.1.5 Proposed level of reach energy efficiency standards

To put forward a reach energy efficiency standard is to cooperate with realization of state energy saving target and to set clear aim for enterprisers, and to promote enterprisers technical innovation. The establishment of standard must objectively evaluate the technical level of home pump manufacturers and widely collect suggestions from enterprisers, industries and related experts, as a result, to make the reach energy efficiency standards that meet actual environment in Chinese market and do greatest contribution to our state's energy saving.

We assume that our country implement mandatory reach standards in 2008 and establish even higher minimum efficiency value for clean water centrifugal pumps, and we have surveyed some enterprisers. The fed back information from those enterprisers surveyed reflected their production and technical conditions. The survey data showed:

- 2.9% for improving 3% on the basis of current product design efficiency
- 25.7% for improving 2% on the basis of current product design efficiency
- 42.9% for same to current product design efficiency
- 22.9% for dropping 2% on the basis of current product design efficiency
- If the minimum allowable of energy efficiency in reach standard is same to the "design point efficiency" of current energy efficiency standard, 41.7% currently have the capability to reach the standard.

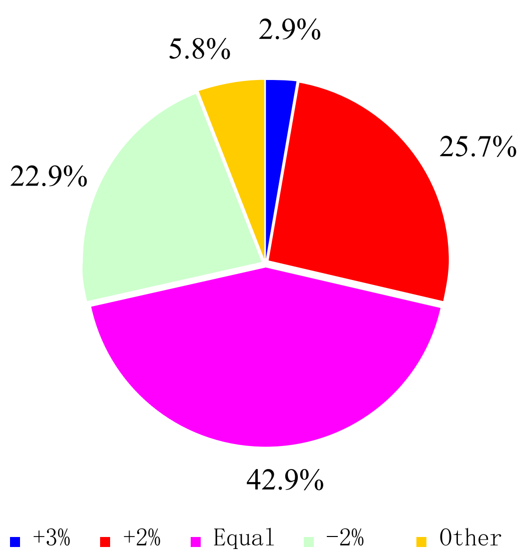

Figure 4-11: Manufacturer Attitudes to Improve Energy Efficiency of CCP

Source: Market Survey Report for CCP

We learn from the market survey that, at present, the design and manufacturing capacity of clean water centrifugal pump manufacturers at home have reached even higher level. Nearly 70% of those manufacturers are capable to produce such products with advanced international level. As to the design point efficiency value defined in the energy efficiency standard for clean water centrifugal pump, 42% of those manufacturers can reach due requirements now.

The manufacturers who approve to take present clean water centrifugal pump design point efficiency value, or raise 2 to 3% based on this value as the reach energy efficiency standard account for 71.5% of total manufacturers. The data above shows sufficiently that the present limited values of energy efficiency for clean water centrifugal pumps can't meet the demand for promoting enterprisers technical innovation and realizing energy saving. Although the survey focused on middle and large scale home enterprisers with strong technical strength, at the same time considering that the enterprisers give conservative suggestions to the mandatory state energy efficiency standard for their own benefit, after discussion with industry associations and experts over and over again, we thought that to take the evaluating values of energy conservation present energy efficiency standards as the minimum allowable in reach energy efficiency standards and take the year of 2008 as expected effective date are reasonable and in accordance with actual status in home and international market.

4.1.6 Energy saving potential of reach energy efficiency standards

We adopt the evaluating values of energy conservation in *Limited values of energy efficiency and evaluating values of energy conservation of centrifugal pump for fresh water* as the minimum allowable in the reach energy efficiency standard for CCP, then the energy saving amount per unit is 2264.33 kWh according the formula (3) above. Figure 4-12 for representing energy saving result is given as:

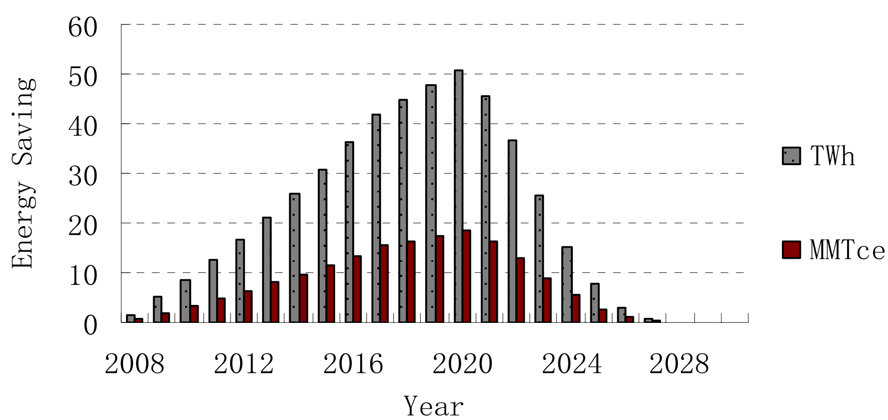

Figure 4-12: Energy Saving Forecast of CCP

From the year of 2018, the first batch of clean water centrifugal pumps will be eliminated after expiration of 10 years service life since the reach energy efficiency standard implements. The increase rate of energy saving amount will slow down resulting from the increase rate of market inventory for clean water centrifugal pump reduces. If the forecast period of this project is up to the year 2020, then energy saving effect resulting from implementation of the reach energy efficiency standard will last to the year 2030 continuously, until all high efficiency clean water centrifugal pumps will be eliminated form the market completely.

According to the result of model analysis, the implementation of reach energy efficiency standard for CCP will result in huge energy saving. As shown in above figure, electric saving amount is going to reach 8.70 TWh, i.e. 3.38 MMTce and 50.81 TWh, i.e. 18.40 in the year of 2010 and 2020 respectively. From 2008 to 2020, accumulative electric saving amount is going to reach 343.72 TWh, i.e. 128 MMTce. At the same time, the peak demand of electric power will be reduced by 200.24 GW.

4.1.7 Emission reduction potential of reach energy efficiency standards

Improving energy efficiency and reducing power consumption can reduce the emission of some atmosphere pollutants such as CO_2, SO_2, NO_x and PM_{10}. Table 4-6 gives the values of CO_2 emission factor for electricity (λ）:

Table 4-6: CO_2 emission Factor for electricity（λ）　　Unit: kg-c/kgce

Data Source	Carbon	Oil	Natural Gas
DOE/EIA	0.702	0.478	0.389
Japanese Energy Resource Institution	0.756	0.586	0.449
China Academy of Engineering	0.680	0.540	0.410
The Greenhouse Gas Control Program under SEPAC	0.748	0.583	0.444
The Climate Change Program under NSFC	0.726	0.583	0.409
The Beijing Program under NSFC	0.656	0.591	0.452

Source: the Audit Method for Enterprise Energy Resource, Meng Zhaoli, Tsinghua University Press

Notes: DOD/EIA is the Energy Information Agency of the Department of Energy, 1999; Japanese Energy Resource Institution, 1999; China Academy of Engineering, *Energy Strategy for Sustainable Development in China*, 1998; State Environmental Protection Administration of China, GEF, *Ways to Control Greenhouse Gases in China*, 1995; NSFC, ADB, *The National Action Study on the Global Climate Oscillation in China,* 1994; NSFC, the Department of Environment of Canada, *Beijing Study of Greenhouse Gas Emission and Control Strategies*, 1994.

Chinese Heat Rate in 2002 is 383 gce/kWh. The value provided by China Academy of Engineering is referenced widely by domestic academia. We also use the value above in this report, namely λ=267.27 g/kWh。

The emission factor of NO_x、SO_2 and PM_{10} are referenced from *Energy Saving Potential Analysis of Chinese Main Energy Consumption Products*:

NO_x：4.07 g/kWh

SO_2：5.84 g/kWh

PM_{10}：24.80 g/kWh

Due to implementation of the reach energy efficiency standard for CCP, the accumulative emission reduction of air pollutants is 96.66 million tons for carbon, 1.51 million tons for nitrogen oxide, 2.17 million tons for sulfur dioxide and 9.22 million tons for particles. As the Figure 4-13 shows:

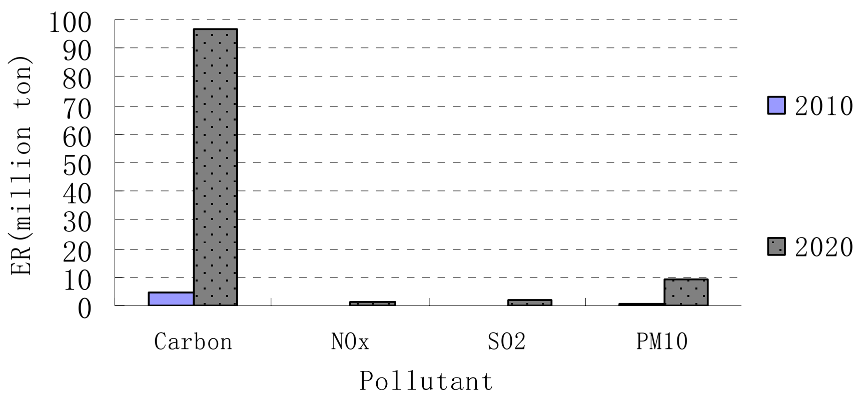

Figure 4-13: Emission Reduction Forecast of Air Pollutants (CCP)

4.1.8 Cost-benefit analysis of reach energy efficiency standards

The cost-benefit analysis of reach energy efficiency standards can explain feasibility to implement the reach energy efficiency standards from the point of economic benefit. First, we determined the quantity of necessary parameters within cost-benefit analysis, such as average common industrial electricity price all over China, average marketing price of clean water centrifugal pump sample, etc.

(1) Electricity price

① Electricity price distribution in 2002

The electricity price differs from different area, industry, consumption time (peak and slack period), consumption amount and other factors. We made a survey to 2002 electricity price data (see Figure 4-14) for civil living, non-civil lighting (public), commercial/common industry and heavy industrial areas in 13 cities and provinces, such as Beijing, Shanghai, Tianjin, Hebei, Jiangsu, Liaoning, Fujian, etc. The arithmetic average value (see Table 4-7) for different areas was calculated without consideration of consumption difference. These average values will be used as electricity price input for cost-benefit analysis of this project.

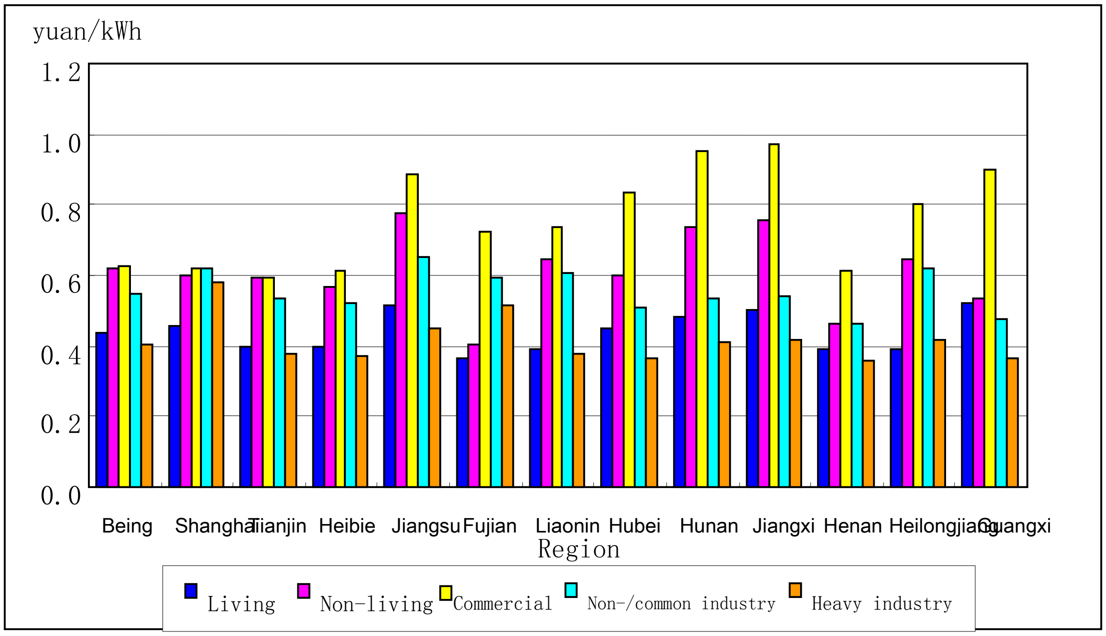

Figure 4-14: Electricity Price Stat. in Some Regions in 2002

Table 4-7: Electricity Price Stat. in Some Regions in 2002 (Yuan/kWh)

Region	Living	Non-living	Commercial	Non-industrial and common industry	Heavy industry
Beijing	0.440	0.62	0.626	0.55	0.406
shanghai	0.445	0.597	0.618	0.62	0.578
Tianjin	0.400	0.593	0.593	0.532	0.387
Hebei	0.400	0.57	0.61	0.519	0.369
Jiangsu	0.515	0.776	0.884	0.649	0.451
Fujian	0.365	0.405	0.725	0.592	0.513
Liaoning	0.392	0.647	0.736	0.607	0.377
Hubei	0.452	0.597	0.832	0.509	0.364
Hunan	0.481	0.735	0.955	0.536	0.411
Jiangxi	0.501	0.755	0.975	0.543	0.418

Region	Living	Non-living	Commercial	Non-industrial and common industry	Heavy industry
Henan	0.391	0.461	0.615	0.461	0.360
Heilongjiang	0.392	0.644	0.805	0.621	0.419
Guangxi	0.520	0.536	0.900	0.474	0.364
Average	0.439	0.610	0.760	0.555	0.416

Source: Provided by State Power Corporation

Note: Electricity price in each field differs with the amount used and industrial electricity price changes among different industries. The electricity prices in the table above are average values of different electricity prices in various regions. The electricity prices for heavy industry do not include basic cost.

For the study object of the project is clean water centrifugal pumps, ventilation fans and displacement air compressors used for industrial application, so we took the average electricity price of non-industry and ordinary industry in 2002, namely 0.56 yuan/kWh.

② Electricity price forecast

The electricity price variation curve could be made in accordance with the average electricity price (see Figure 4-15) of some power companies all over China from 1990 to 1999. And the electricity price variation trend in some years of future can be forecasted with consideration of actual condition.

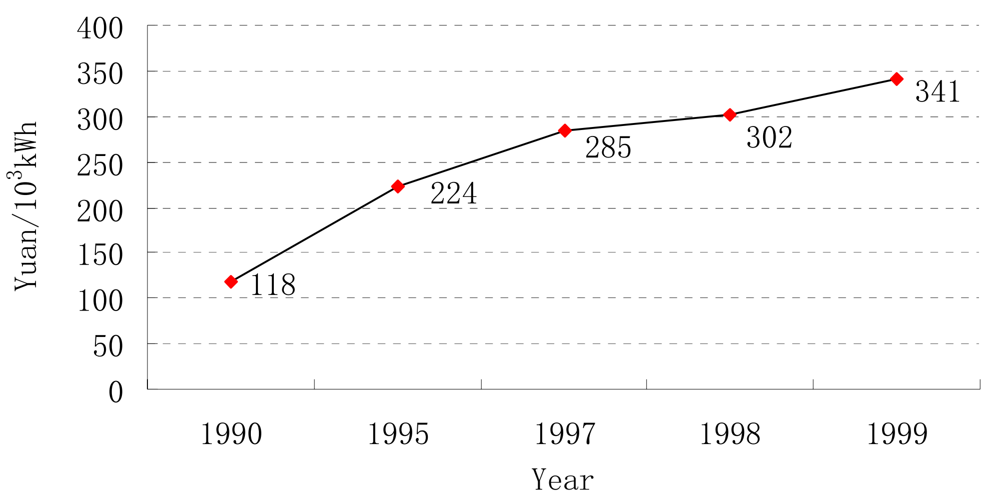

Figure 4-15: Average electricity price distribution of each power gird of State Power Corporation from 1990 to 1999

Source: Provided by State Power Corporation

The electricity price variation trend shown in Figure 4-15 indicated the annual increase rate of electricity price from 1990 to 1999 was 18.9%, but the increase rate slowed down in the last two years with 10% around. The electricity price was kept same from 1999 to 2000 on the whole. We took the ten-years electricity price variation as basic point to speculate the electricity price variation trend before 2020 in the industrial area in our country with logarithm regression method and got the forecast result shown in Figure 4-16.

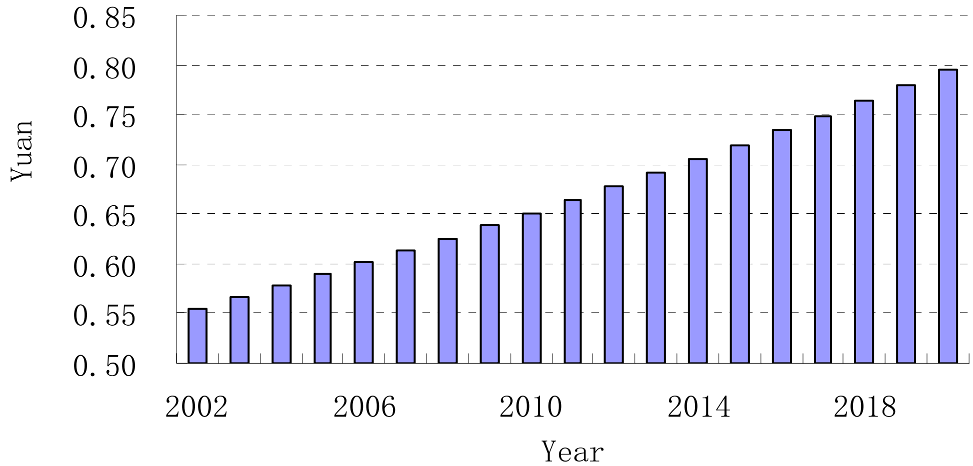

Figure 4-16: Average Electricity Price Forecast of Common Industry (2002～2020)

We can figure out that the electricity price of ordinary industries in our country for the future would increase by a speed of 2% each year based on the forecast data. Although power shortage happened as the economy boosted in recent years, the condition are expected to relax three years later with the development of Three Gorges Project and speeding up of power construction. Moreover, the electricity price for civil application would keep relatively stable. So we forecasted that the national electricity price for civil application would increase smoothly. To keep 2% increase rate for the future is reasonable comparatively.

(2) Unit product price

According to the 2003 Chinese Mechanical & Electrical Price Catalogue published by the China Statistic Publishing House, considering the marketing principle that the price for same type of product under market economic condition should be competitive, the statistic for sales price of clean water centrifugal pump in 2003 was made among some state backbone enterprises, such as Anhui Sanlian Pump Industry Limited Corporation. The clean water centrifugal pump of 15 kW driving power is sold at an average price of 7,344 yuan on the market. According to the report made by US Department of Energy (DOE) in 1996, the price would increase 25% as the energy efficiency increase 15%. Based on above information, we figured out that the implementation of the reach energy efficiency standard in China for clean water centrifugal pump would make the average sales price of high-efficiency pump increased to 8,168 yuan from7,344 yuan.

(3) Cost-benefit analysis

Based on the formula (16) and (17), we introduced unit price increment into the corresponding formula and calculated the forecast value of investment increment for reach energy efficiency standard project of clean water centrifugal pump (See Figure 4-17). By the end of 2020, the net currency value of this project would be 13.76 billion Yuan.

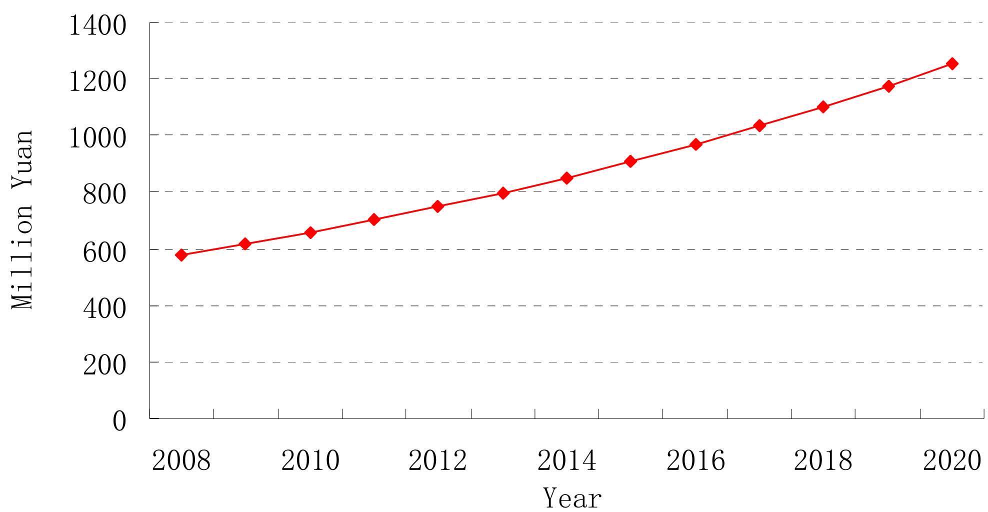

Figure 4-17: Investment Increment Forecast of CCP

On the other hand, we did benefit forecast analysis to this project on the basis of the formula (16) and (18),. We learned from the description above, the manufacturing cost variation for the project was reflected by the product's price increment, and the utilization cost variation was measured by reduction of product's energy consumption. By multiplying the annual energy saving amount of clean water centrifugal pump to forecast electricity price for industrial application in corresponding year, we could get the energy saving economic benefit from the year 2008 to 2030 result from high-efficiency clean water centrifugal pump. See Figure 4-18 for detail calculation result:

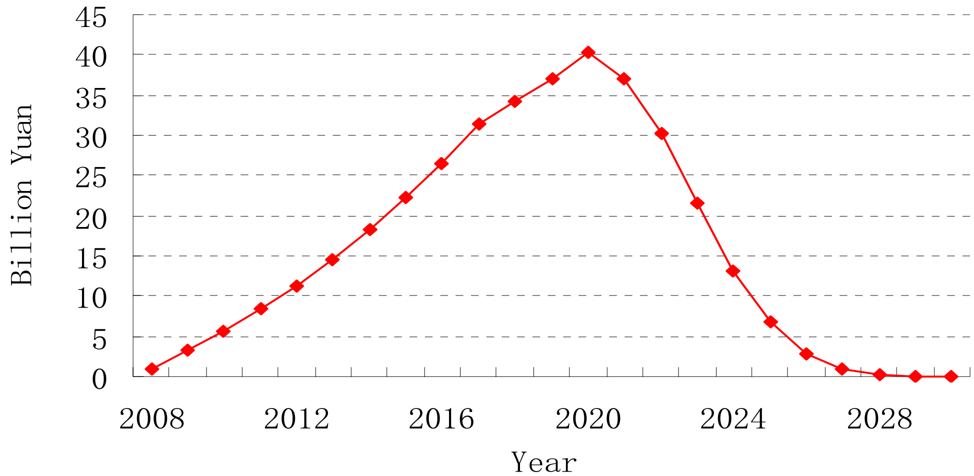

Figure 4-18: Economic Benefit Forecast due to Energy Saving of CCP

From 2008 to 2030, the energy saving benefit resulted from improving efficiency standard for clean water centrifugal pump would be 166.71 billion yuan. Compared with investment increment, the net income of project would be 152.95 billion yuan. The ratio between benefit and cost would be 12.11, and the payback time of some product would be around 0.7 years.

4.2 Fans

4.2.1 General situation

(1) Basic Description

① Definition

Fans are the usual name for air compression and air conveying machinery in China. As a rule, fans include ventilation fans, blowers, compressors and roots blowers, but not include displacement blowers and compressors such as piston compressor. Air compressor and air conveying machinery is referred to the ones that can converse mechanical energy into air pressure energy and kinetic energy and then convey the air and get it out.

② Classification

There are mainly eight kinds of fans in the fan manufacturing industry as centrifugal compressor, centrifugal ventilation fan, axial ventilation fan and other fans with special purpose, which can be lined in 230 product series of 4500 specifications. Quite a few of them fill the technical blankness and can meet the basic requirements to match the import projects in china. Fans are wildly employed in various sectors like petrochemical industry, metallurgy, mines, textile, construction, and etc. There are some types of fans that reach the present advanced international standards, including air compressors, ammonia refrigerant condensers and natural gas condensers matched with ammonia equipment with annual output up to 300,000 tons, axial compressors matched with oil refining catalytic and cracking units with annual output up to 800,000 tons, axial compressors for blast furnace and axial fans used in 300～600 MW power stations.

According to operating principle and structure, fans can be classified in the following:

Blade fans: energy transferred to fluid through whirling of working impellers.

Displacement fans: energy transferred to fluid through the periodic displacement of operating chamber.

Table 4-8. Product Categories of Fan

<table>
<tr><td rowspan="10">Fan</td><td rowspan="3">Blade Fan</td><td colspan="2">Centrifugal Fan</td></tr>
<tr><td colspan="2">Axial-flow Fan</td></tr>
<tr><td colspan="2">Mixed-flow Fan</td></tr>
<tr><td rowspan="7">Displacement Fan</td><td rowspan="3">Reciprocating Fan</td><td>Piston Fan</td></tr>
<tr><td>Plunger Fan</td></tr>
<tr><td>Diaphragm Fan</td></tr>
<tr><td rowspan="4">Rotary Fan</td><td>Screw Fan</td></tr>
<tr><td>Roots Fan</td></tr>
<tr><td>Foil Fan</td></tr>
<tr><td>Sliding Vane Fan</td></tr>
</table>

According to the outlet pressure (or lifting pressure), fans can be classified as follows:

- Ventilation fans (low pressure) < 15 kPa;
- Blowers (medium pressure): 115 kPa ～ 350 kPa;
- Compressors (high pressure)> 350 kPa.

Notes: above parameters are defined under the condition of temperature 20^0C and atmospheric pressure 101 Pa.

③ Main performance parameters

The main performance parameters of fans include flux (can be divided into deflation and delivery amount), pressure, gaseous media, rotary speed, power, etc. (see Table 4-9).

Table 4-9: Main Performance Parameters of Fan

Item		Unit	Remark
Flowrate	Flowrate Capacity	m^3/min、m^3/h、kg/s	
	Rated Flowrate Capacity	m^3/min(NTP)、m^3/h(NTP)	
Pressure	Static, Increasing and Total Pressure	Pa、MPa	
Gas Medium	Temperature	°C	
	Humidity	%、kg/h	
	Density	kg/m^3(NTP)	
	Dust Type	g/m^3、g/m^3(NTP)、g/min	Abrasion and Causticity
	Gas Type		Erosion and
Rotate Speed		r/min	Sliding Variable and Invariable
Power	Output Power	kW	

Source: *Manual of Fan,* China Mechanism Industry Press

④ Typical performance curve

The performance curve of fans is the graphic analysis. Usually the correlation curve of main performance parameters of fans is referred to performance curve or characteristic curve of fans. The performance curve of fans is the display mode of laws of the inner movement and it can be determined by measurements. The performance curve of fans includes: air quantity-total wind pressure curve (Q-HT), air quantity-static wind pressure curve (Q-HST), air quantity-efficiency curve (Q-η) and air quantity-axial power curve (Q-N). It can be done from any flux point of pumps to determine a group of corresponding wind pressure, power and efficiency values. This group of parameters is called working condition, simply speaking operating mode or mode point. Traditionally, all these parameters are measured manually. At present, it's popular to employ computer-based data collection system and processing module that dramatically decreases the cost and reduces labor input through displacing the original experimental measurements. The computer-based data collection system and processing module have improved the data precision and reliability, and realized continuous data measurements.

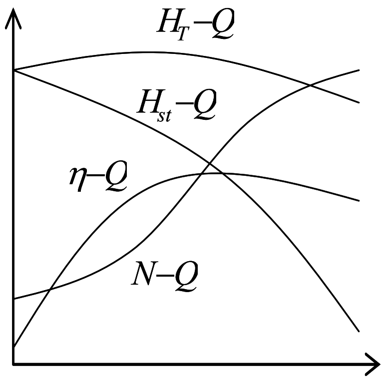

Figure 4-19: Typical characteristic curve of Fan

Source: *Manual of Fan,* China Mechanism Industry Press

(2) Market analysis

According to the statistics made by China General Machinery Fan Industry Association to its 80 members, the fan industry produced 247,375 sets in 2001, 3.9% lower than the former year.

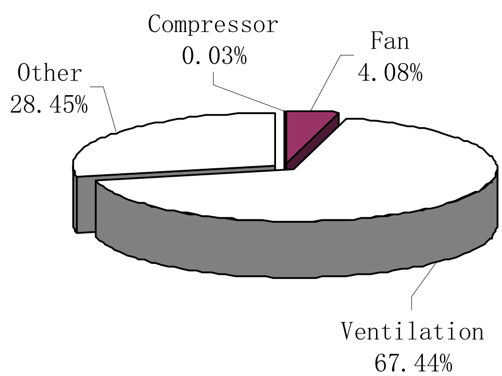

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Figure 4-20: Market Share of Fans in 2001

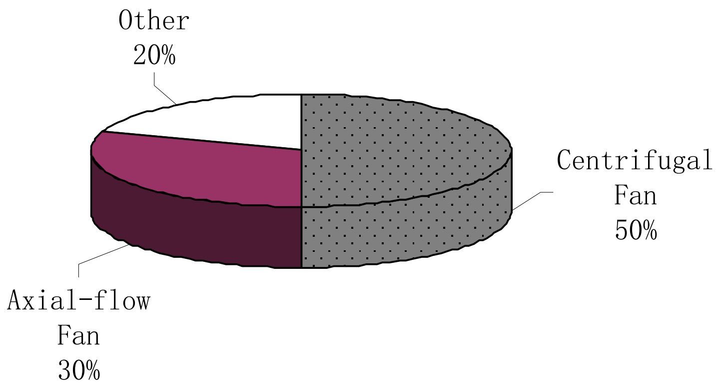

Figure 4-21: Market Share of Ventilation Fans in 2001

Source: *China Machinery Industry Yearbook 2002*2

We can see from the above two figures that the ventilation fan occupies absolute majority market share, other types of pumps are non-standard products designed and manufactured in accordance with customer's requirements; the non-standard products already accounts for 28% of market share. And the air compressor occupied the least market share. There are only a few manufacturers being capable to produce centrifugal compressor, axial compressor, such as Shenyang Fan Factory, Shanghai Fan Co., Ltd. and Shan'xi Fan (Group) Limited Company. Most other manufacturers mainly produce centrifugal ventilation fans and axial ventilation fans. So, the focus to promote energy saving should be laid on ventilation fans in fan industry.

4.2.2 Energy consumption analysis

(1) Basic data

① Average service life of products

It is found that the small-size ventilation fan less than 10 kW has a normal running period of 8.9 years, lower than the products above 10 kW, the ventilation fan above 100 kW has an average service life of 10.8 years.

- 0-10 kW，average life 8.9 years;
- 11-50 kW，average life 9.5 years;
- 51-100 kW，average life 9.8 years;
- ＞100 kW，average life 10.8 years.

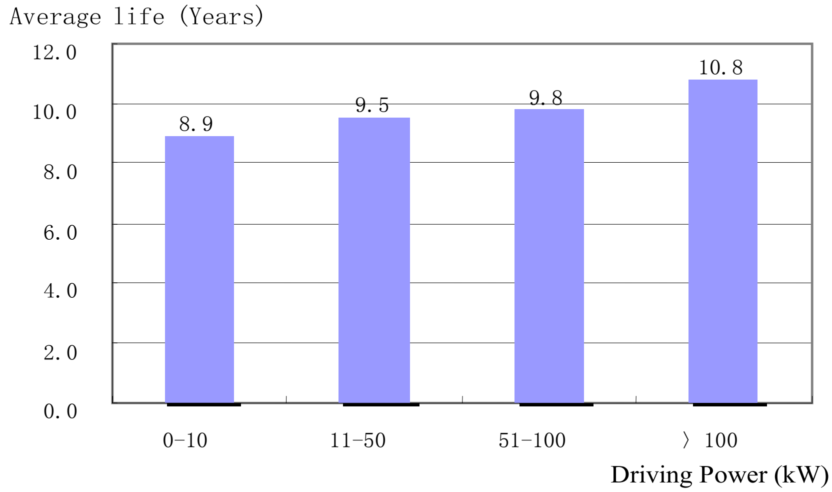

Figure 4-22: Average Life for Different VF

Source: Market Survey Report for VF

The average service life of ventilation fans increases as the driving power increases, but the average life for products with different driving power is 9.75 years. In the same way, we take 10 years as the average service life for ventilation fans in order to simplify the calculation.

② Output and market inventory

The output of ventilation fan is estimated as below: Based on the statistic data made to 80 backbone enterprisers within fan industry in 1999, 2000 and 2001 by the China Machinery Industry Annual, and reckoned the output of clean water centrifugal pump in 2002 and 2003 referring to the increase speed published by the China Machinery Industry Annual 2004, these five years data was taken as basic point, the average annual increase rate was calculated based on expectation of future output trend of clean water centrifugal pumps with logarithm regression analysis method. See following figure for estimated result:

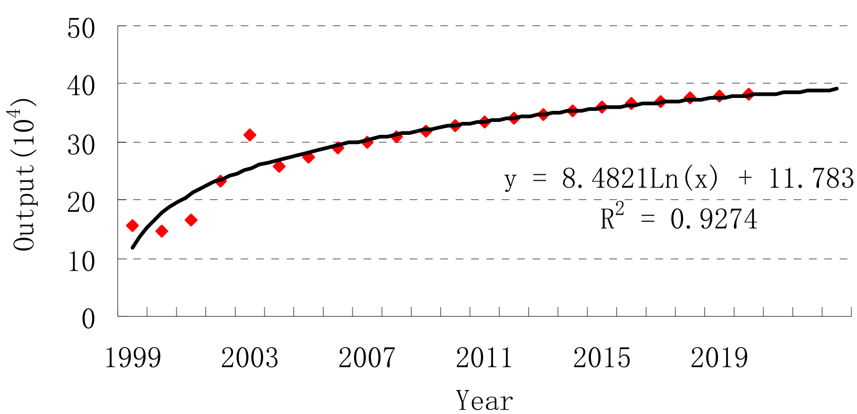

Figure 4-23: Output Forecast of VF

The average annual increase rate of output of ventilation fans was calculated 6.46% based on expectation result. Some experts and professional agencies forecast the speed will be close to 12% in the future, but we take the data in the China Machinery Industry Annual as basic point to keep consistent with the centrifugal pump project. For there is only data on output but no sales quantity in the statistic annual, we can assume that the average sales index (ω) of ventilation fan is 0.98. The sales amount of ventilation fan for present year is obtained by multiply the index by the output in this year.

Under similar condition, we need to spread the statistic data to the whole country. The annual output of ventilation fans by scale manufacturers is regarded as the total ventilation fan output in the country. In 2001, there were 237 fan manufacturers on certain scale all over the country, 80 enterprises were members of the Fan Industry Association. After discussion of experts and associations time and again, it was assumed that the output of non-association enterprises was 40% of those members. Then, the forecast result of ventilation fan market inventory all over China is as below:

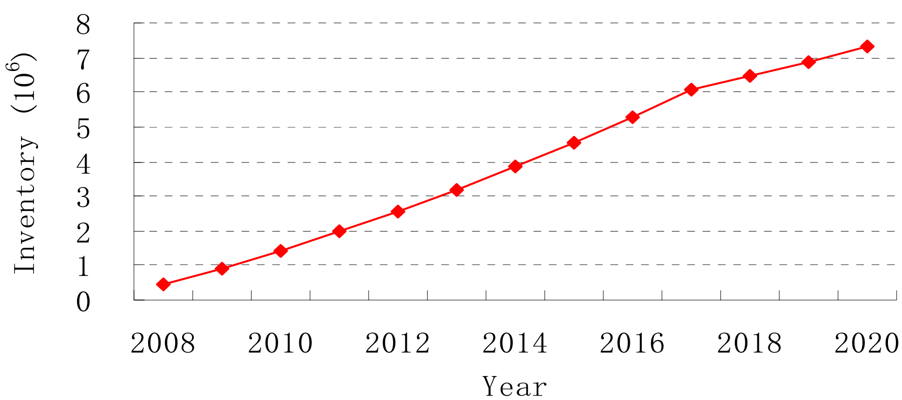

Figure 4-24: Inventory Forecast of VF

③ Average driving power

The survey given priority to nature determination also involved average driving power evaluation of the ventilation fan products. Although the data were roughly evaluated by the production department of enterprise, the statistic result could reflect the general situation and trend of ventilation fan driving power in our country. Among all surveyed enterprises, nearly 50% estimated the average driving power of their products was less than 100 kW, about 24% was 100-200 kW, 27% was above 200 kW. See the following figure for detail:

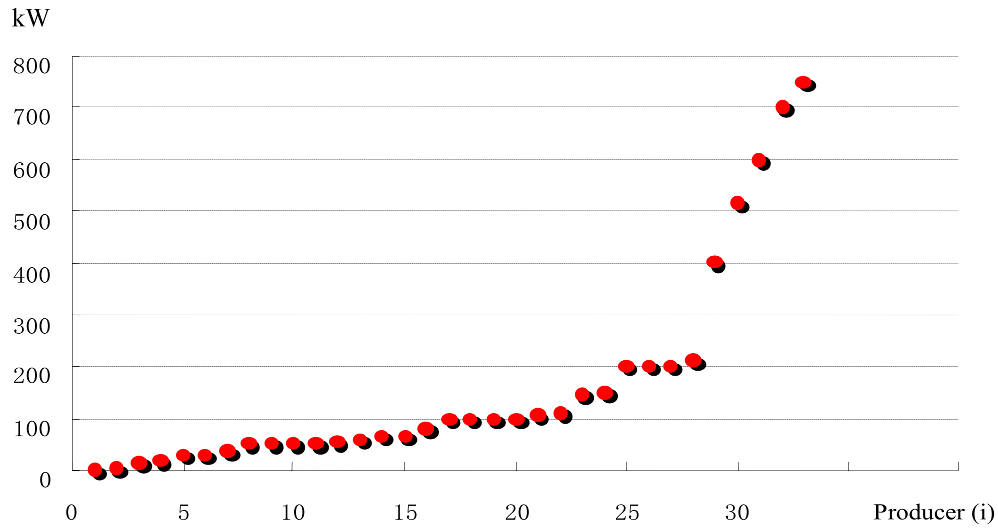

Figure 4-25: Driving Power Trend of VF

Source: Market Survey Report for VF

The distribution of average driving power shown by the survey only reflected the trend and general situation, with no exact value available. Similar with the calculation method for clean water centrifugal pump, we use the survey data of electromotor. Although the survey data corresponds to different product range, allowing for the ventilation fan accounting for majority share of home fan market, we use the survey result of electromotor project to calculate the average driving power of ventilation fans. The Figure 4-26 represents the driving power distribution of ventilation fan:

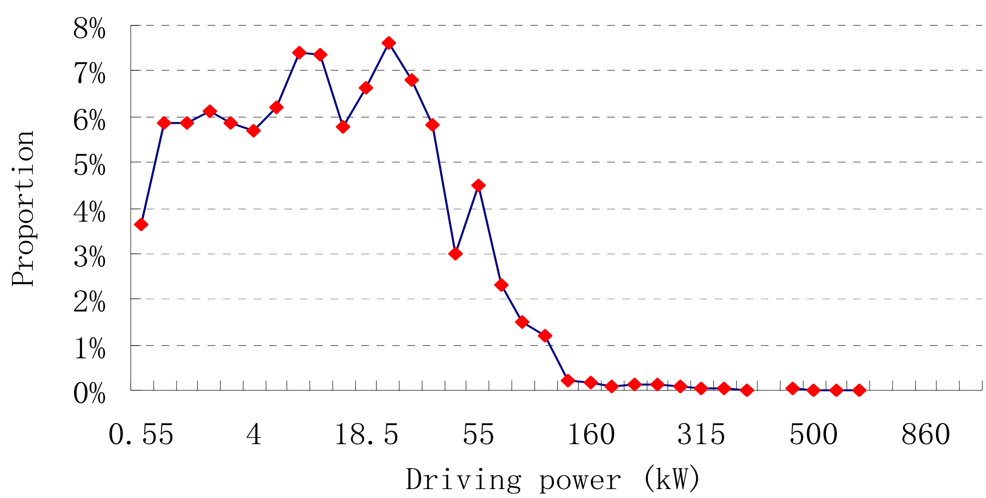

Figure 4-26: Driving Power Distribution of VF

Source: Market Survey Report of Medium and Small Three Phase Asynchronism Electric Motor

We assume the driving power distribution will maintain the same in the future fan industry. So, based on the estimated market inventory in 2008, we can calculate the average driving power of ventilation fan in home market to be 20.71 kW.

④ Average operation time

Average operation time of VF is shown in Table 4-10 as follows:

Table 4-10: Operation Time Stat. of VF

SN(i)	1	2	3	4	5	6	7	8
Time Scale	0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-24
Frequency(ψ_i)	0.1	0.3	0.6	0.9	0.9	0.9	0.6	0.2
Average Annual Operation Time(T_{av})	$T_{av} = \sum_{i=1}^{8} \psi_i \times \frac{24}{8} \times 365 = 4927.5$ hours/year							

Source: Market Survey Report of Medium and Small Three-phase Asynchronism Electric Motors

The average running time of 13.5 hours per day can be calculated from statistic data in Table 4-10. We also can assume a compound parameter ϕ to reflect the factors may influence annual electricity consumption, such as the proportion of pump product used in industry area and running rate. If we assume the compound parameter ϕ=0.5, we can get the equivalent annual running time of clean water centrifugal pump is 2463.75 hours.

(2) Energy consumption forecast

At present, the national standard *Limited values of energy efficiency and evaluating values of energy conservation for fan* is already in publicizing period. This national standard will be regarded as principle to calculate criterion energy consumption amount and forecast amount. We take a certain type ventilation fan under a group of certain parameters condition to calculate the criterion energy consumption amount and forecast amount after the energy saving analysis method for clean water centrifugal pump.

The selected sample was centrifugal ventilation fan with pressure factor 0.8, specific rotary speed $30 \leq n_s < 45$, $5 \leq \text{Size} < 10$. According to the national energy efficiency standard for fans, based on above-mentioned condition, we can get the limited value of energy efficiency 74%, design point efficiency 77%, evaluating value of energy conservation 80%. So the energy consumption of ventilation fan is forecasted as follows:

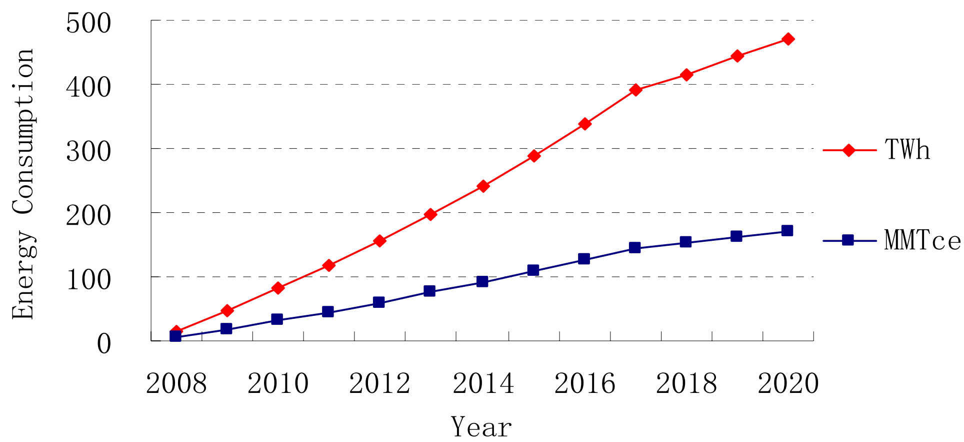

Figure 4-27: Energy Consumption Forecast of VF

Figure 4-27 shows that if the ventilation fans keep current energy efficiency, the energy consumption amount will be very enormous. It is forecasted that electric consumption by ventilation fans will be 81.64 TWh, i.e., 31.76 MMTce in 2010 and increase significantly to 471.32 TWh. i.e., 171 MMTce in 2020.

4.2.3 Technical resolution for energy saving

The enterprise must strengthen technical research capability to improve the design efficiency of ventilation fans and reach the requirements of energy efficiency standards, not only learn the advance design technique of ventilation fan in our country, but also pay attention to leading international design technique and experience all the time. There are many factors could effect the design efficiency of ventilation fan, such as impeller design, selection of material for ventilation fan shell, profile design, etc. Only after resolving the key parameter selection that affects the design efficiency of ventilation fan, the design efficiency of ventilation fan could be improved as a whole.

(1) Centrifugal ventilation fans

The centrifugal impeller design is the key part of ventilation fan design. For a long period of time, the impeller is always designed with flowing channel conception, and developed to starting from the flowing channel of limited blade to make potential flux theory analysis of two or three-dimensional nonstick flux, until to simulate current field variation with large computer software (e.g. Computational Fluid Dynamics-CFD). People always build up and design optimized theory structure in virtue of measurement of internal current field of rotary impeller. The high efficiency centrifugal impeller can be designed with consideration of following optimized tactics:

① Optimize the entrance width of impeller

The impeller loss and feature are affected greatly by the flowing situation at impeller entrance. How to reduce its loss must be taken into consideration during design. On the one hand, increase the elbow curvature radius from axial to radial ξ ($\xi=F_0/F_1$), select ξ=1, the air current at entrance accelerates, relax separation trend of air current and reduce second flow; on the other hand, reduce value ξ ($\xi<1$) also depress separation trend of air current.

② Optimize entrance and exit diameter ratio and the air entrance angle

Under the situation with same flux Q, same impeller rotation speed n, same impeller outside diameter d_2, different entrance and exit diameter ratio (d_1/d_2), the relative speed at entrance are variable. The loss within impeller and momentum depth variation of blade channel interface are related with W_1, only when $W_1=W_{1min}$, the impellor loss is less; when considering flown line curvature and leakage effect, than:

$$(d_1/d_2)_{OPT}=\left[\xi Q\sqrt{2}\frac{\psi m}{1-\gamma^2}\right]^{1/3},tg\beta_{OPT}=\frac{1}{\sqrt{2}}*\frac{1}{m}$$

In this formula, where m is impeller radial speed ratio at entrance, m is the function of ratio of entrance width b to curvature radius at entrance R'_1, $\frac{1}{m}=\frac{1}{3}(1+2e^{-\frac{b_1}{2R'_1}})$, ψ is sluice coefficient , and $\psi=1+\frac{\Delta Q}{Q}$.

$(d_1/d_2)_{OPT}$ educed with above-mentioned formula matches with relevant small angle of attack and will make the actual highest efficiency point flux measurement very close to design flux with normal error less than 5%.

③ Optimize impeller outlet parameter b_2, blade exit installation angleβ_{2b} and blade number Z

When the design flux Q, Pressure head H, rotation speed n and outside diameter of impeller d_2 are determined during design, there is a group of optimal values of b_2, β_{2b} and Z objectively. The statistic result shows that there is linearity relationship between impeller exit parameter and ratio rotation speed very clearly. There is direct relationship between blade exit installation angle β_{2b} and fan performance and noise feature. So, taking all factors into consideration, it has no close relationship with other major geometric parameters. However, the determination of other parameters should meet requirements of designed pressure head. If the parameters do not meet the requirements, β_{2b} may be adjusted without changing other impeller parameters.

④ Optimize meridian surface molding

The meridian surface molding is the molded line to limit front plate. The air channel formed by front and rear plate is named meridian channel. The center of optimization principle is to reduce jet stream, namely laminar flow, as a result to diminish second flow.

$$\frac{d_{cm}}{d_s} = const$$

The variation law of air flowing speed along the flown line is used to being adopted, but the straight cone shaped front plate (e.g. conical arc shape) is more favorable without turn point and too strict elbow. Consequently the second flow is reduced.

⑤ Optimize gyration molding (blade to blade) and load distribution of blade

The design of impeller blade must be accompanied with assured pneumatic performance and lowest loss, as well as precise and economic machining. Therefore, the integral relation formula must be met:

$$\int_1^2 \delta pbrdr = \frac{Q\psi H}{\omega Z} E$$

Where: Q is design flux; H design full pressure; Z blade number; ψ coefficient of leakage, E coefficient (1.2～1.3); ω wheel angle speed.

The load distribution of designed blade molding line ensures the required flux and pressure head.

(2) Axial ventilation fan

① Adopt rational double entrance air channel

The transmission part on middle and large size axial ventilation fan is located generally at the inlet side of the air channel. Because the ventilation fan's electromotor, transmission shaft and impeller are on the same central line, the suction port of air entrance channel must be away from the body's axial line for some distance to enforce the air entrance channel to be curvilinear arranged. Whether the curvature radius, section shape and joining part's structure is logical or not, they may greatly influence the ventilation fan's efficiency.

② Optimize design of ventilation fan's blade

The impeller is central part of the ventilation fan. Paying attention to improvement of impeller blade of ventilation fan may achieve unexpected effect to the ventilation fan's efficiency. For example, to replace aerofoil blade with net type distorted blade may increase the ventilation fan's air volume, air pressure and efficiency. However, the designers must pay attention to the thickness, weight and dimension of the distorted blade. In addition, there may appear second flow phenomenon at the gap of fan's blade end. It may limit energy loss caused by second flow to reduce the blade end's gap.

③ Optimize integral design

The whole fan is made up of fan's rotor, fan's housing and other fixed parts, such as fan's shank. The correlation among them should be studied with caution because it may not only affect fan's efficiency, but also the source of noise.

④ Utilize advanced testing technology

The developed countries made great investment to promote aviation development, energy saving project, such as turbine generator, turbo machine, etc. and developed a series of advanced testing technologies. As far as the fan's design, from thermal wire anemometer to high-speed pressure sensor, even to laser application, such as Laser Doppler Velocimeter (LDV) and Particle Image Velocimetry (PIV), all these technologies can be transferred into fan's design research to assist cutting down internal energy loss of ventilation fan and laying solid foundation to improve fan's design efficiency.

⑤ Utilize Computer Aided Design (CAD)

The Computational Fluid Dynamics (CFD) software has been used in engineering area widely. Just like other CAD software, the emergence of CFD brings great convenience to fan design engineers. AFD provides designers with detailed flowing information (velocity, component of force, pressure and temperature distribution) and manages geometric complexity related with fan, such as blade distortion, modifying flowing separation, vortex, noise, stagnancy, reflux, etc. The CFD is also used to calculate the existing and new type of fan's performance precisely, and to test the design selection under various conditions. The designers may judge design effect through adjusting any factors affect fan's efficiency, thereby to optimize design through numerous calculation based on related theory.

(3) Technical personnel's suggestion

The manufacturers of ventilation fans recommend following technologies (See Table 4-11).

Table 4-11: Measures to Improve Efficiency of VF

1	CFD technology
2	Advanced Model (such as NEW3ACE)
3	Improving the materials of vanes
4	CO_2-protectiong welding
5	Improving flowline of impeller
6	Improving punching technology
7	Optimum design of ternary flow
8	Improving manufacturing precision
9	Improving combination of syphons
10	die spinning technique

4.2.4 Comparison of domestic and abroad energy efficiency standards

(1) China current energy efficiency standards and other relative standards

- Limited values of energy efficiency and evaluating values of energy conservation for fan
- GB/T 1236-2000 Performance testing of standardization wind way for industrial ventilation fan
- GB/T 10178 Ventilation fan field testing
- GB/T 13274 Axial ventilation fan Technology requirements
- GB/T 13275 Centrifugal ventilation fan Technology requirements
- JB/T 2977 Glossary of fans

(2) Abroad current energy efficiency standards and other relative standards

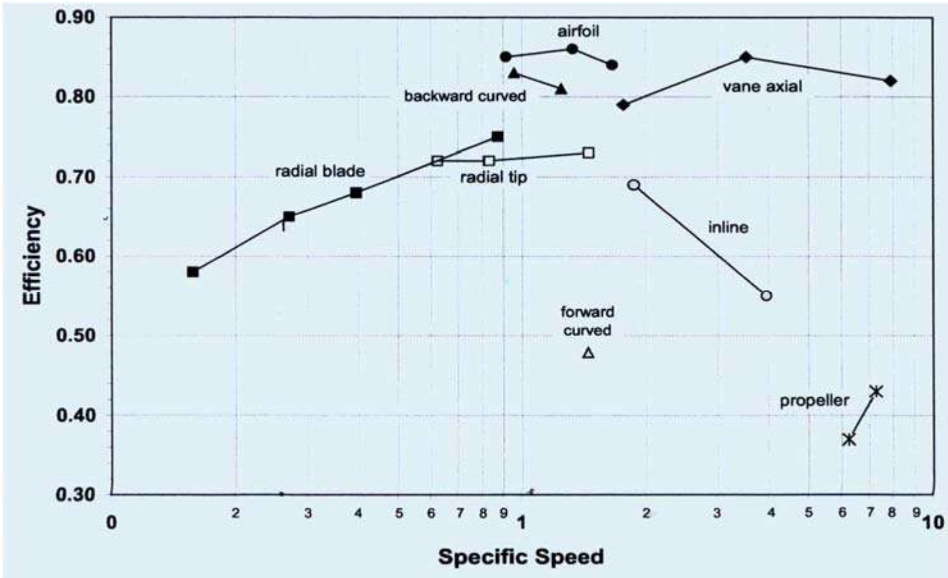

Figure 4-28: Efficiency Comparison of Different Fans

The survey result of efficiency to various types of ventilation fans made by European Union is shown in Figure 4-28. We can see from the figure that, design plans with different style, impeller profile and similar blade inclination, along with material may influence the ventilation fan's efficiency greatly. Generally speaking, compared with the ventilation fan's efficiency level in European Union, the limits defined in our energy efficiency standards are too low. It also represents that the energy efficiency standards for ventilation fan have potential to be improved.

4.2.5 Proposed level of reach energy efficiency standards

For the sake of reasonable determination of energy efficiency standard indexes for ventilation fans and understanding the actual production technology level of the ventilation fans manufacturers in our country, we did a survey on expectation to reach index and product's advancement aiming at manufacturers. The survey data indicated:

- 12.1% for improving 3% on the basis of current product design efficiency
- 33.3% for improving 2% on the basis of current product design efficiency
- 24.4% for same to current product design efficiency
- 12.1% for dropping 2% on the basis of current product design efficiency
- If the minimum allowable of energy efficiency in reach standard is same to the "design point efficiency" of current energy efficiency standard, 24.2% currently have the capability to reach the standard.

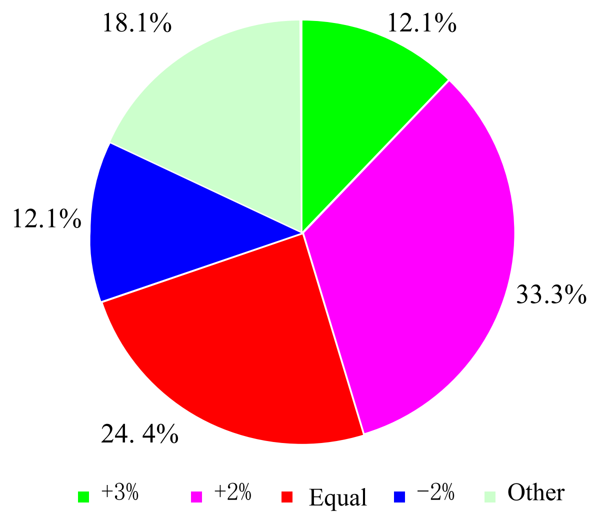

Figure 4-29: Manufacturer Attitudes to Improve Energy Efficiency of VF

Source: Market Survey Report for VF

In comparison with the market survey data of clean water centrifugal pump, the production technology level for ventilation fan was quite lower. Although 70% enterprises agreed that the reach index should be equal or over the efficiency value of present design point, only 24.2% of them thought they were capable to reach the design point efficiency. Moreover, most survey objects were major manufacturers in the industry with strong technical force, namely representatives for high level of production technology. The suggestions given by manufactures were conservative for protection of their own benefit, but the design point efficiency value was still even high at present. It is reasonable to take design value as MEPS in the reach standard taken effect after three years and consistent with the actual market condition in our country.

4.2.6 Energy saving potential of reach energy efficiency standards

Taking the product design point energy efficiency in *Limited values of energy efficiency and evaluating values of energy conservation for fan* as the minimum values of reach energy efficiency standard, the result of energy saving by ventilation fans is given as Figure 4-30:

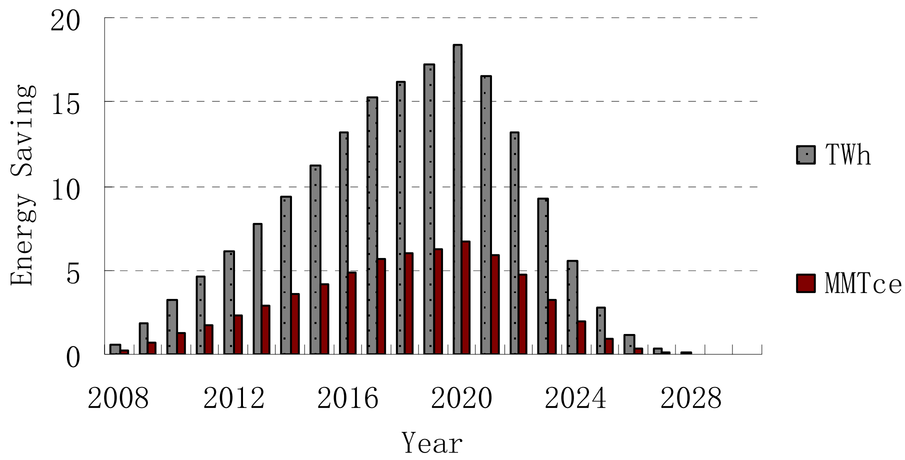

Figure 4-30: Energy Saving Forecast of VF

Figure 4-30 shows that the reach energy efficiency standard of ventilation fan will save electric power as 3.18 TWh, i.e. 1.24 MMTce in 2010 and 18.36 TWh, i.e. 6.65 MMTce in 2020. From 2008 to 2020, the accumulative energy saving amount will reach 124.87 TWh, i.e. 46.47 MMTce. Meanwhile it will reduce peak demand by 56.74 GW in 2020.

4.2.7 Emission reduction potential of reach energy efficiency standards

According to the result of model analysis, implementation of reach energy efficiency standard will result in accumulative emission reduction of 35.12, 0.55, 0.79 and 3.35 million tons for carbon, nitrogen oxide, sulfur dioxide and particles respectively (See Figure 4-31).

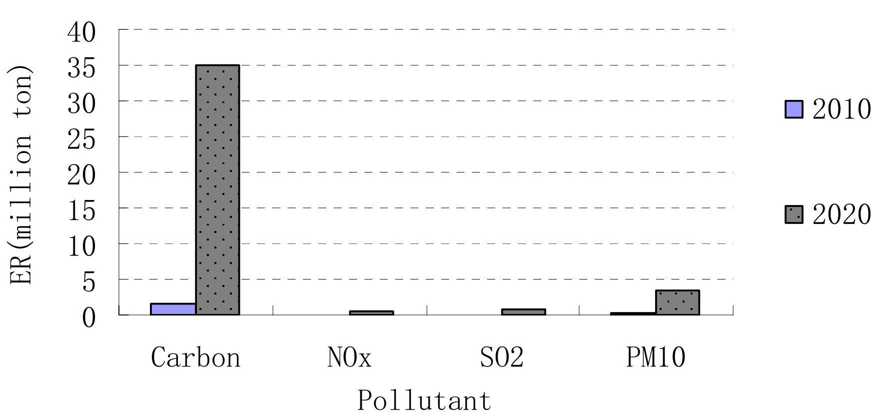

Figure 4-31: Emission Reduction Forecast of Air Pollutants (VF)

4.2.8 Cost-benefit analysis of reach energy efficiency standards

Similar with that of clean water centrifugal pump, the Cost-benefit analysis of reach energy efficiency standards for ventilation fan could explain the feasibility to implement the reach energy efficiency standards from the point of economic benefit. Meanwhile we determined the quantity of necessary parameters within cost-benefit analysis, such as average common industrial electricity price all over China, average marketing price of ventilation fan sample, etc. We have already had average common industrial electricity price in our country in the report of clean water centrifugal pump, so we took 0.56 yuan/kWh as calculation criterion in the following analysis.

According to the *2003 Chinese Mechanical & Electrical Products Price Catalogue* published by the China Statistic Press, considering the marketing principle that the price for the same type of product under market economic condition should be competitive, the statistic for sales price of ventilation fan in 2003 was made among some state backbone enterprises, such as Guangzhou Xinghua Environment Protection Equipment Co, Ltd. The ventilation fan with 18.5 kW driving power is sold at an average price of 14,600 yuan on the market. According to the report made by US Department of Energy (DOE) in 1996, the price would increase 15% as the energy efficiency increase 10%. We figured out based on the above information that the implementation of reach energy efficiency standards in China for ventilation fan would make the average sales price of high-efficiency pump increased to 15488 yuan from 14600 yuan. The cost-benefit analysis method for ventilation fan was exactly the same as clean water centrifugal pump. So here we only gave calculation results.

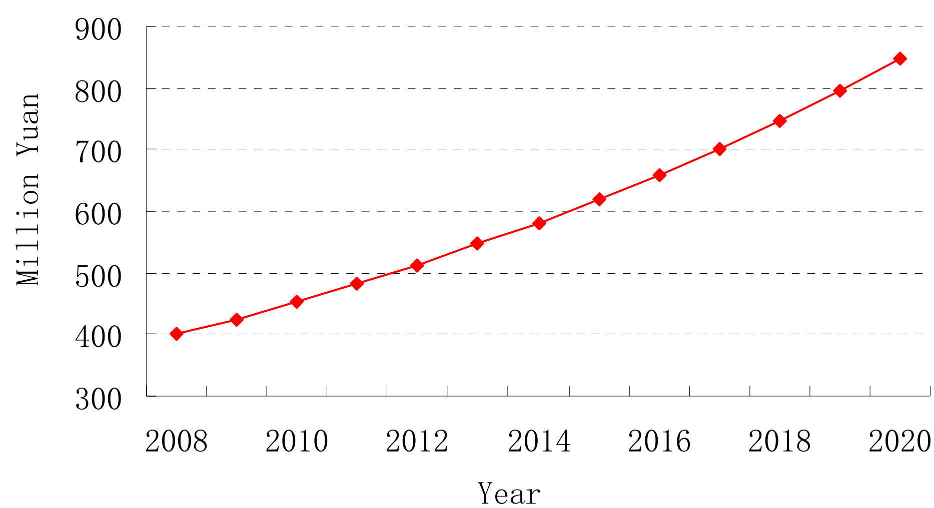

Figure 4-32: Investment Increment Forecast of VF

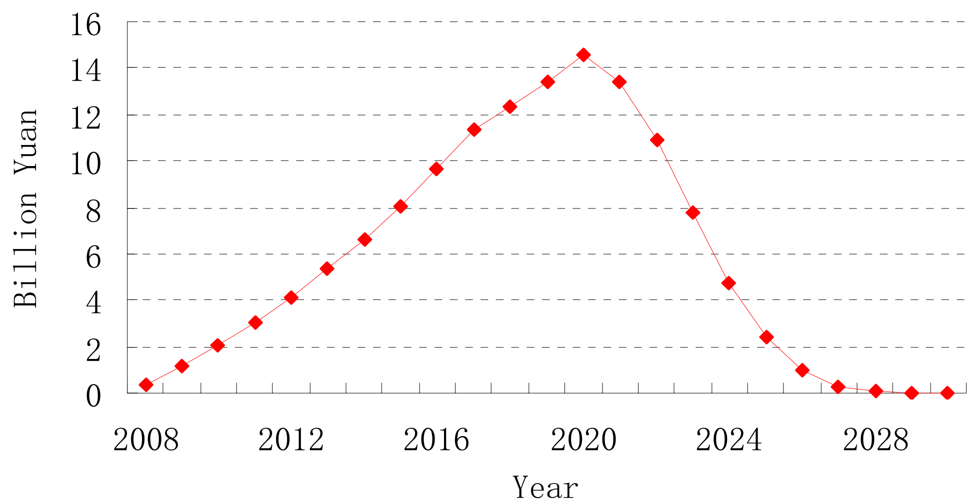

Figure 4-33: Economic Benefit Forecast due to Energy Saving of VF

The investment increment for high-efficiency ventilation fan would increase year after year as the ventilation fan sales increase. We assumed the currency conversion rate as 7.6%, so by the end of 2020, the net currency value of the investment would be 4.53 billion yuan. However, the energy saving benefit result from this project would be 60.52 billion yuan. Compared with investment increment, the net income of project would be 55.99 billion yuan. The ratio between benefit and cost would be 13.35, and investment reclaim period of each product would be less than half year.

4.3 Air compressors

4.3.1 General situation

(1) Basic Description

① Description

Compressors are a kind of machinery equipment widely used in industrial production. This machinery is used to increase pressure through compressing the gotten air depending on its piston movement to-and-fro in the air cylinder or rotation action of rotor to meet production demand.

② Type

Air compressors can be divided into displacement compressor and driving according to working principle or compressor classification standard GB/T4976-1985 (equivalent to ISO05390-1977).

Table 4-12: Product Categories of Air Compressor

Air Compressor	Dynamic Air Compressor	Jet Air Compressor	————
		Turbo Compressor	Centrifugal
			Axial-flow
	Volumetric Air Compressor	Rotary Air Compressor	Rotor
			Screw
			Vanes
		Reciprocating Air Compressor	Piston
			Diaphragm

Source: *Practical Manual of Mechanism Appliance,* China Chemistry Industry Press

Driving compressor: a compressor to get higher kinetic energy relying on high velocity rotation impeller acting on air and then rapidly drop down velocity within pressure diffusing equipment to transfer gas kinetic energy into potential energy. The driving style mainly consists of two basic types, namely centrifugal type and axial type.

Displacement compressor: a compressor to increase static pressure by consequently sucking certain volume gas and discharging the gas out of enclosed container through motive parts displacement. The displacement style consists of two types, namely rotary type and reciprocal type.

Rotary type: piston, also named rotary rod, rotate; rotor number is not certain; gas cylinder shape differs. The rotary type consists of rotor type, thread rod type, slide type, etc.

Reciprocal type: piston move to-and-fro; gas cylinder has cylindrical profile. The reciprocal type consists of piston type and film type. The piston type is the most widely used type at the present time.

③ Major performance parameters

Displacement flux: The displacement flux of piston compressor often refers to compressed air volume discharged by last stage of compressor per minute. Converse the result to air volume under suction condition at first stage standard with unit of m^3/min.

Discharging air pressure: refers to meter indication of last stage discharging air of the air compressor with unit of Pa.

Power ratio: it's energy efficiency index defined by present state or industry standard for air compressors. Its physics definition refers to power consumed by unit air discharging volume at stipulated operation condition with unit of kW/m^3/min.

(2) Market analysis

In 2003, there are 105 member enterprises and 9 new members to be approved in the Compressor Branch of China General Machinery Industry Association; among them, the minorities are scientific research institutes, while the majorities are compressor or relative parts manufactures and related enterprises, accounting for one forth of the total enterprises in the same trade in China. The air compressor belongs to production license management range with about 400 licensed enterprises, 100 other manufacturers, so totally about 500 enterprises. Thirty enterprises among them have annual production value over 100 million yuan, 50 have production value from 30 to 100 million yuan, others below 30 million yuan.

According to the statistic data from State Statistic Bureau, the increase rate of annual total production of air compressor in our country from 2001 to 2003 is 51.56%, 35.52 % and 58.7% accordingly. Our air compressor industry has entered a new period with rapid growth. In 2003, there are totally 2411 scale enterprises with the general machinery industry in our country, among them 156 compressor manufacturers. It is estimated that the annual output of compressor on home market is over 3 million sets. The displacement air compressor plays a leading role definitely on industry demand and output. It is estimated by experts that, in 2000, the output of micro/small size and large displacement air compressor is 800,000 and 30,000 sets accordingly. Most products are made by rapid growing private-owned enterprises.

As early as in 1987, the total installation power of compressor station within machinery industry already reached 9×10^5 kW with electricity consumption of 3.5×10^5 kWh every hour and annual consumption of 1.3×10^9kWh; however, the total power supply was 68.647 billion KWh at that time. And only the electricity consumption of compressor station within machinery industry accounted for 2% of total power supply in China. It was indicated by the energy balance statistic of most machinery industry enterprises: the electricity consumption of compressor station accounted for 5 to 20% (average 10%) of total enterprises electricity consumption, some even reached 30%. According to rough statistic, the electricity consumption of air compressor accounted for 10% of total power supply in our country. It's very important to energy saving and environment protection to lower down energy consumption of air compressor and improve the energy efficiency of air compressor.

4.3.2 Energy consumption analysis

(1) Benchmark data

① Average product’s service life

Integrating evaluation data collected from various enterprises, it’s found that the average normal service life of small-size displacement air compressor less than 10 kW was 9.5 years, lower than the compressor over 10 kW. And the compressor over 100 kW reached 12.3 years.

- 0-10 kW， average life 4.1 years;
- 11-50 kW， average life 7.3 years;
- 51-100 kW， average life 8.0 years;
- ＞100 kW， average life 9.8 years.

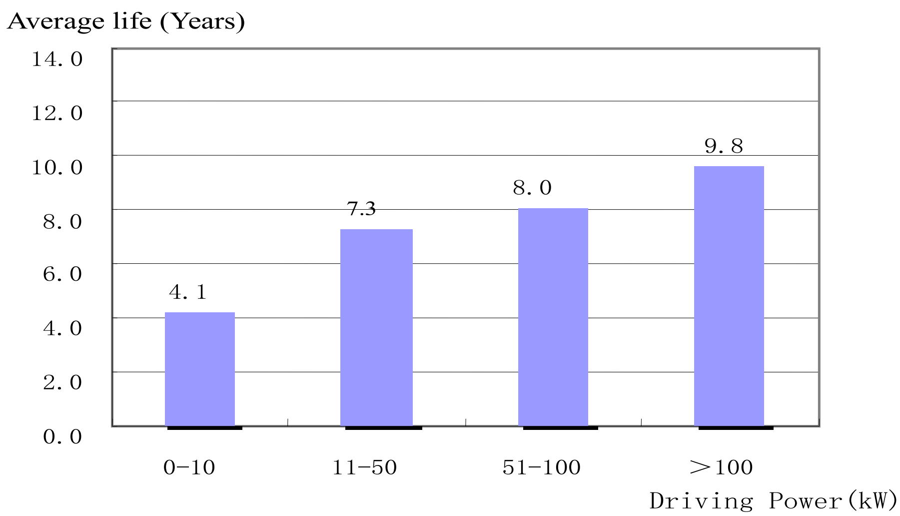

Figure 4-34: Average Life for Different DAC

Source: Market Survey Report of DAC

Generally speaking, the service life of displacement air compressor ranges very differently. For large and middle size displacement air compressor, the normal service life is rather long; the micro and small size short. The statistic data in the figure above may roughly represent the service life trend of displacement air compressor in China. To utilize energy saving model to analyze micro, small and middle size compressor, along with middle and large size displacement air compressor take type ZB-0.1/8 and LW-10/10 reciprocal piston air compressor as sample accordingly. The average service life for these two types of compressors mentioned above is four and eight years respectively.

② Output and inventory

The annual output of displacement air compressor in 2000 was taken as basic point to make evaluation. It’s estimated by experts that the output of micro and small size displacement air compressor was 800,000 sets in the year 2000; middle and large size 30,000 sets. Based on evaluation above, referring to the statistic data published by the *China Machinery Industry Annual 2004*, on the assumption that the increase speed for air compressor were as same as the displacement air compressor, the future output trend of displacement air compressor was forecasted and the average annual increase rate was calculated with logarithm regression analysis method. See following forecast result:

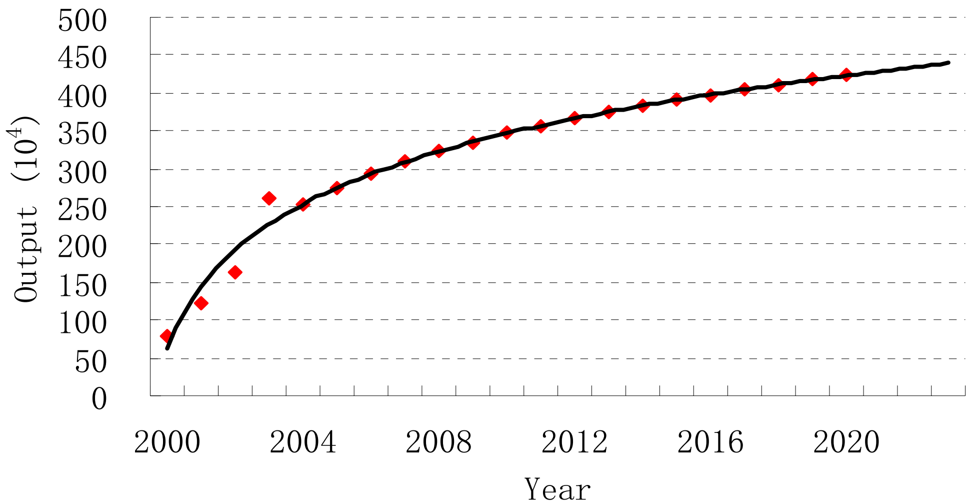

Figure 4-35: Output Forecast of DAC(Small/Micro-type)

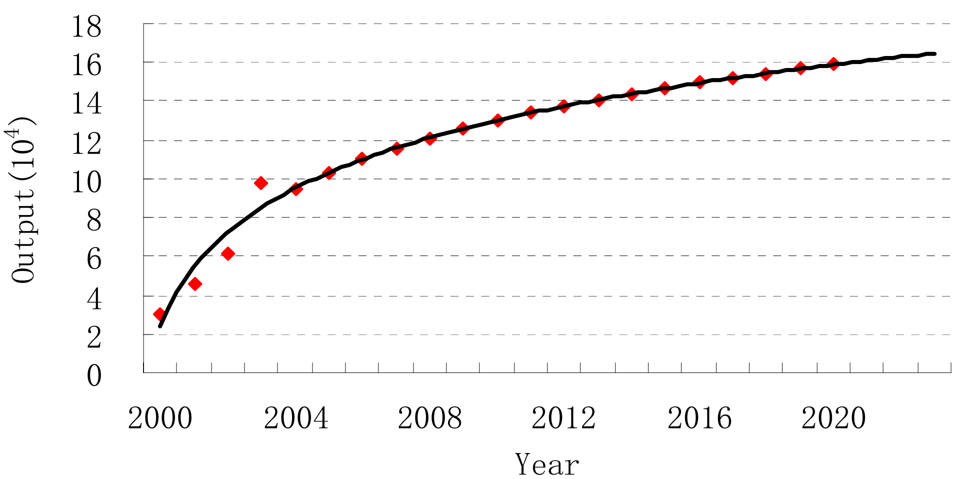

Figure 4-36: Output Forecast of DAC (Medium/Big-type)

The average annual increase rate of output of displacement air compressor was calculated 12.3% based on expectation result. We assumed the average sales index (ω) of displacement air compressor was 0.98. The sales amount of displacement air compressor for that year could be figured out by multiply the sales index to the output in the corresponding year. Then the total market inventory could be calculated. The calculation result is shown below:

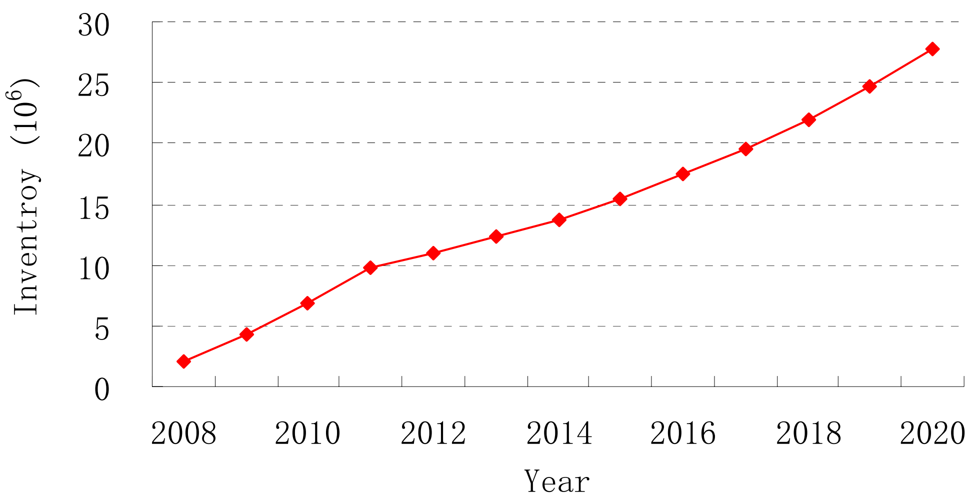

Figure 4-37: Inventory Forecast of DAC (Small/Micro-type)

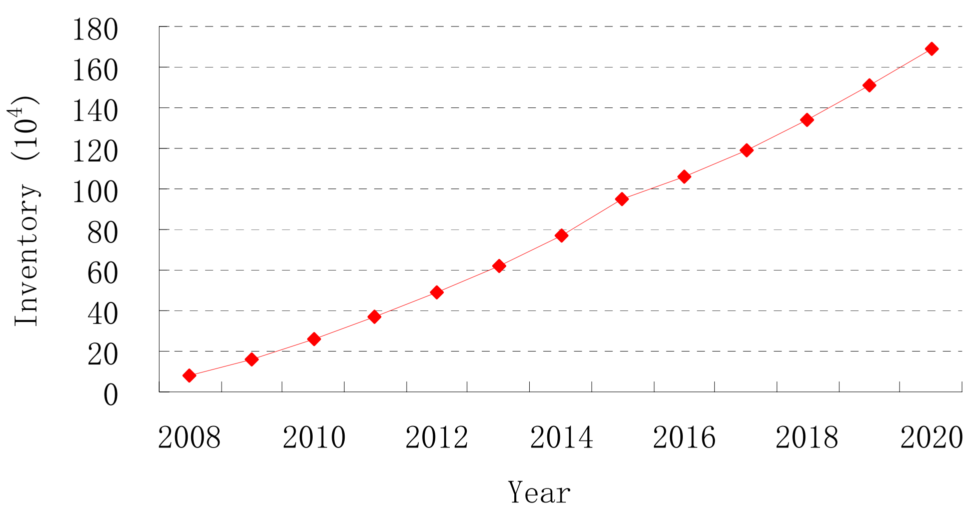

Figure 4-38: Inventory Forecast of DAC(Medium/Big-type)

④ Average operation time

According to the survey feedback, the utilizing rate of DAC in different time period is shown in Table 4-13.

Table 4-13: Operation Time Stat. of DAC

SN(i)	1	2	3	4	5	6	7	8
Time Scale	0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-24
Frequency(ψ_i)	0.1	0.2	0.6	0.9	0.9	0.9	0.5	0.3
Average Annual Operation Time(T_{av})	$T_{av} = \sum_{i=1}^{8} \psi_i \times \frac{24}{8} \times 365 = 4818$ hours/year							

Source: Market Survey Report of Medium and Small Three-phase Asynchronism Electric Motors

The average running time of 13.2 hours per day can be calculated from statistic data in Table 4-13. Assuming a compound parameter ϕ to reflect the factors may influence annual electricity consumption, such as the proportion of pump product used in industry area and running rate and assume the compound parameter ϕ=0.5, we can get the equivalent annual running time of clean water centrifugal pump is 2409 hours.

(2) Energy consumption forecast

The national standard *Limited values of energy efficiency and evaluating values of energy conservation for displacement air compressors* (GB19153) was issued by General Administration of Quality Supervision, Inspection and Quarantine of P.R.C in 2003. Imitating the approach of energy saving analysis used for CCP and VF, energy saving amount of DAC can be calculated on the basis of the values in above standard.

The selected two samples were ZB-0.1/8 and LW-10/10 standing for micro/small and medium/big displacement air compressors respectively. ZB-0.1/8 is a mirco reciprocating piston DAC with single compressing stage, 1.5 kW driving power, 0.8 MPa discharging pressure and 0.1m$^{3/}$s volumetric flowrate; LW-10/10 is a medium fixed reciprocating piston DAC with 45 kW driving power, 0.8 MPa discharging pressure, 2.5 m^3/s volumetric flowrate.

According to GB19153, the limited values of energy efficiency and evaluating values of energy conservation are 12.5 kW/m^3/min and 11.1 kW/m^3/min respectively for ZB-0.1/8, 8.12 kW/m^3/min and 7.64 kW/m^3/min respectively for LW-10/10. Therefore, the energy consumption can be calculated as follows:

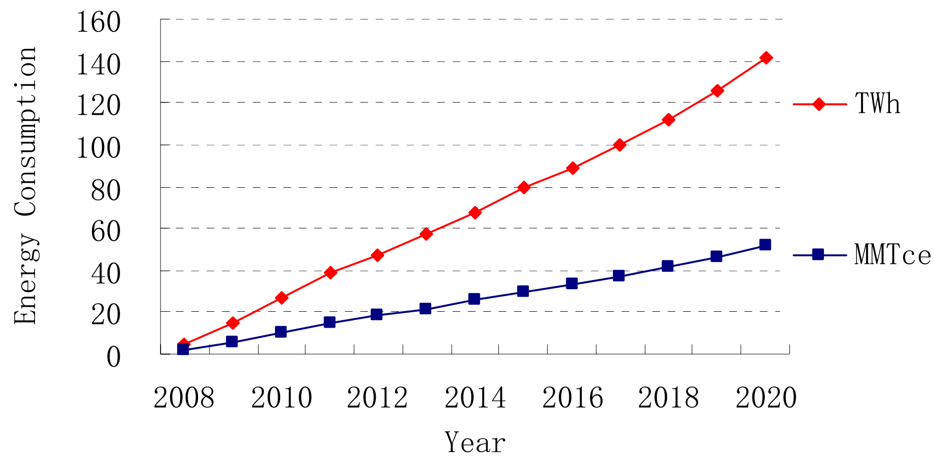

Figure 4-39: Energy Consumption Forecast of DAC

If displacement air compressors keep current efficiency, power consumption will reach 26.42 TWh to 2010 year, i.e. 10.28 million tons coal and 141.78 TWh to 2020 year, i.e. 51.34 million tons coal.

4.3.3 Technical resolution for energy saving

As to the reciprocal compressor, we can achieve energy saving through improving structure of inlet valve, outlet valve, nonreturn valve, piston ring to reduce friction and air resistance loss and optimize matching between compressor body and driving motor. As the rotary compressor, we can achieve energy saving through improving meshing profile, reducing resistance loss of filter unit, such as oil-gas separator, and pressure valve to increase the belt's transmission efficiency.

At present, there are some new technologies in favor of improving efficiency of general equipment. The manufacturers of displacement air compressor ratify following technologies.

Table 4-14: Measures to Improve Efficiency of DAC

1	Introduction of new materials
2	Improve design of valves
3	Improve gas entering system and pipeline technology
4	Improve fittings
5	Airproof technology
6	Computer numerical control technology
7	Structure technology

8	Gas valve improvement and noise reduction
9	Improve manufacturing accuracy and use new type equipment
10	Improve aerodynamic performance

4.3.4 Comparison of domestic and abroad energy efficiency standards

(1) China current energy efficiency standards and other relative standards

- GB19153-2003 *Limited values of energy efficiency and evaluating values of energy conservation for displacement air compressors*
- GB/T4975-1995 *Glossary of displacement air compressors General rules*
- GB/T13279-2002 *Fixed reciprocating piston displacement air compressors for general utilization*
- GB/T13928-2002 *Micro reciprocating piston displacement air compressors*
- JB/T8933-1999 *nil-oil reciprocating piston displacement air compressors*
- JB/T8934-1999 *Portable direct-connecting reciprocating piston displacement air compressors*
- JB/T4253-2002 *oil-spray vane displacement air compressors for general utilization*
- JB/T6430-2002 *oil-spray screw displacement air compressors for general utilization*
- GB/T3853-1998 *Examination for displacement air compressors*
- GB10892-1989 *Fixed air compressors Safety rules and work regulations*
- JB8524-1997 *Displacement air compressors Safety requirements*
- JB/T53054-1999 *Reciprocating piston displacement air compressors for general utilization product quality classification*
- JB/T53056-1999 *oil-spray screw displacement air compressors for general utilization product quality classification*
- JB/T53225-1999 *oil-spray vane displacement air compressors for general utilization product quality classification*

(2) Abroad current energy efficiency standards and other relative standards

The ISO/TC118 ("Compressor, Pneumatic Tool and Pneumatic Machinery Committee" of international standardization organization) established a series of related international standards: ISO1217 *Inspection & Acceptance Testing for Displacement Air Compressor*, ISO3857 *Glossary of Compressor, Pneumatic Tool and Machinery*, ISO5390 *Compressor Classification*, PTC9 *Performance Testing Criterion for Displacement Air Compressor,* *Vacuum Pump and Fan* issued by ASME (American Society of Mechanical Engineers), DIN1952 *Utilizing Aperture Plate, Nozzle and Venturi Tube Embed in Round Section and Being Filled with Fluid to Measure Flux of Fluid (VDI Flux Measure Principle)*, BS1517 *Testing Criterion For Displacement Air Compressor and Exhauster*, etc.

The energy efficiency standard noted in the present state of Industry standard for compressor product refers to "specific power". It represents power consumption of unit exhausting amount under nominated working condition. There is no uniform international standard of energy efficiency index and energy efficiency classification for compressor yet. Larger compressor manufacturers abroad establish energy efficiency index themselves usually. The energy efficiency index for piston type air compressor in our country is equivalent to large companies abroad on the whole. Some are even better than abroad. However, as to thread rod or slide rotary air compressor, the related energy efficiency index still has big gap with large companies abroad.

4.3.5 Proposed level of reach energy efficiency standards

For the sake of reasonable determination of energy efficiency standard indexes for displacement air compressor and understanding the actual production technology level of the displacement air compressor manufacturers in our country, the ideas and suggestions of key enterprises, industries, universities, research institutes and related experts were collected to make the reach energy efficiency standard meeting the actual condition in Chinese market, so as to do most contribution to the state energy saving.

(1) Survey of enterpriser attitude toward energy efficiency standards

It was indicated by survey data that the air compressor manufacturers were positive to improve product's energy efficiency standards and promote manufacturers' production technology level.

- 7.3 for improving 3% on the basis of current product design efficiency
- 41.5 for improving 2% on the basis of current product design efficiency
- 34.1 for same to current product design efficiency
- 12.2% for dropping 2% on the basis of current product design efficiency
- If the minimum allowable of energy efficiency in reach standard is same to the "design point efficiency" of current energy efficiency standard, 24.2% currently have the capability to reach the standard.

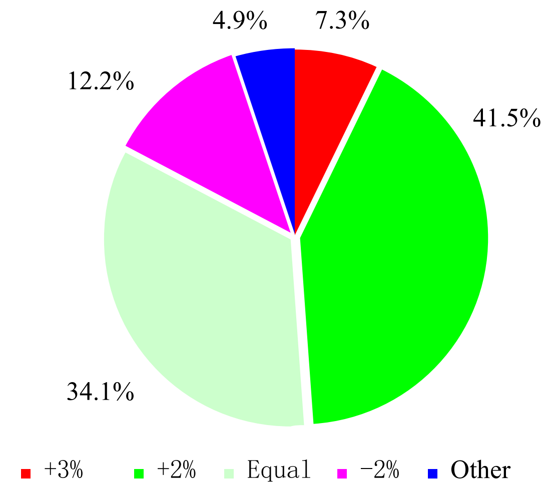

Figure 4-40: Manufacturer Attitudes to Improve Energy Efficiency of DAC

Source: Market Survey Report for DAC

(2) Product's energy efficiency level

According to the statistic figure based on inspection data of air compressor specific power tested by the State Compressor Refrigeration Equipment Quality Supervision & Inspection Center since 1985, we can see from Figure 47 that, the excellent class proportion of various types of compressors was 18%, 55% reached first class, 20% just up to grade, and 7% rejected.

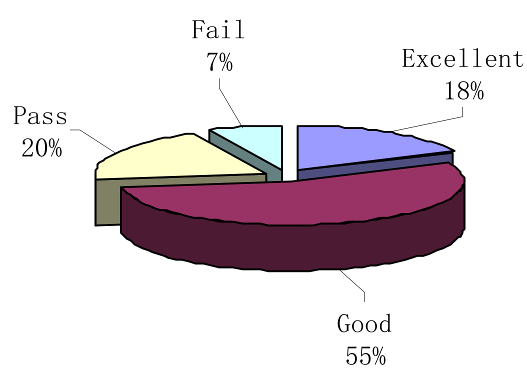

Figure 4-41: Specific Power Distribution of DAC

Source: National Quality Supervision and Testing Center of DAC

The limited values of energy efficiency and evaluation values of energy conservation for displacement air compressors were converted from the specific power indexes defined in present product's standard, namely specific power eligible product's index defined in product quality classification standard. It's shown that the specific power coverage was still in lower level. The energy saving evaluation value was converted on the assumption that 20 to 30% compressors were energy saving products based on the inspection data statistic made by the State Compressor Refrigeration Equipment Quality Supervision & Inspection Center. As to piston compressor, the specific power index was converted based on the average value of excellent and first class product of classification standard. As to thread rod compressor, the specific power index was converted based on excellent class product of classification standard and increase another 3% on the result. The calculation for slide compressor took thread rod compressor as reference.

Integrating survey to enterprises and product quality inspection statistic data, the manufacturers who approve to take present design point efficiency value or above as the reach energy efficiency standard account for 82.9% of total manufacturers. One third of the manufacturers were capable to reach the design point efficiency during present period. According to statistic data made by the State Compressor Refrigeration Equipment Quality Supervision & Inspection Center since 1985, 37% of products reached the first class level. Therefore, we can take the energy saving evaluation value in GB19153-2003 as the energy efficiency limit in the reach energy efficiency standard for displacement air compressor.

4.3.6 Energy saving potential of reach energy efficiency standards

According to the energy saving calculation formula for unit DAC, the amount of annual energy saving is 337.26 kWh for micro/small DAC（ZB-0.1/8）and 6745.2 kWh for medium/big DAC（LW-10/10）. Integrating the market inventory, national energy saving amount due to introduction of high efficient DAC can be represented by Figure 4-42 as follows:

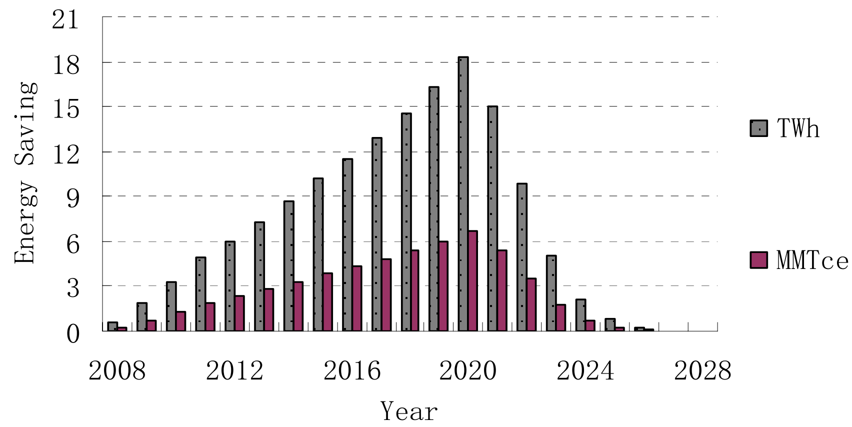

Figure 4-42: Energy Saving Forecast of DAC

Figure 4-42 shows that the reach energy efficiency standard of displacement air compressors will bring enormous energy saving by 3.30 TWh, i.e. 1.28 MMTce in 2010 and 18.35 TWh, i.e. 6.65 MMTce in 2020. Accumulative energy saving from 2008 to 2020 will reach 116.59 TWh, i.e. 43.40 MMTce. Simultaneously, it will reduce the peak demand by 54.18 GW in 2020.

4.3.7 Emission reduction potential of reach energy efficiency standards

The implementation of reach energy efficiency standard of DAC will accumulatively reduce 32.79 million tons carbon, 0.51 million tons nitrogen oxide, 0.73 million tons sulfur dioxide and 3.13 million tons particles.

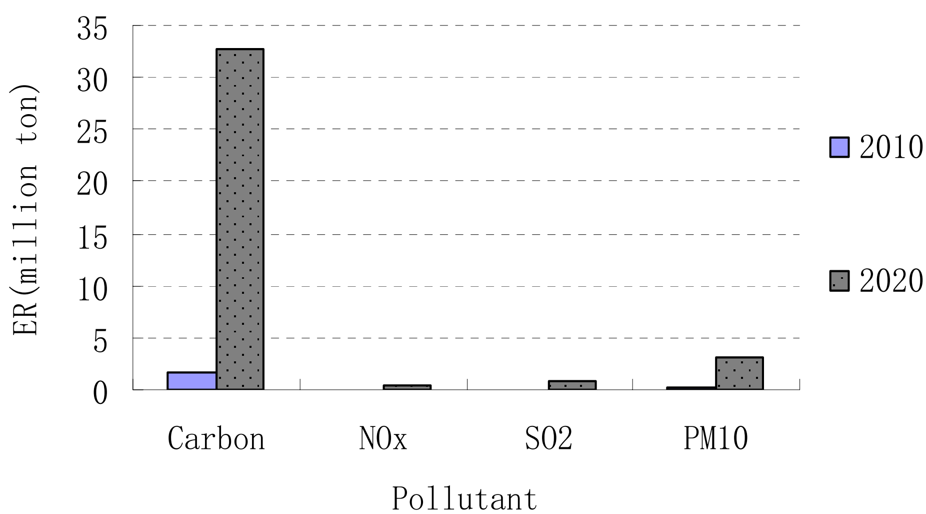

Figure 4-43: Emission Reduction Forecast of Air Pollutants (DAC)

4.3.8 Cost-benefit analysis of reach energy efficiency standard

According to the project life cycle cost method mentioned above, we determined the quantity of necessary parameters within cost-benefit analysis, such as average common industrial electricity price all over China, average marketing price of displacement air compressor, etc. We had the average common industrial electricity price in China in the clean water centrifugal pump analysis part of this report, so we took 0.56 yuan/kWh as the calculation standard in our analysis.

According to the 2003 Chinese Mechanical & Electrical Price Catalogue published by the China Statistic Press and experts' evaluation, the present average price of middle & large size, micro & small size representative compressor product in the project is 70,000 yuan and 400 yuan on the market accordingly. According to the report made by US Department of Energy (DOE), the price would increase 25% as the energy efficiency increase 25%. We figured out based on the above information that the implementation of reach energy efficiency standard in China for these two types of displacement air compressor would make the average unit cost increased 4,138 yuan and 45 yuan accordingly. We could get following results with project life cycle cost analysis:

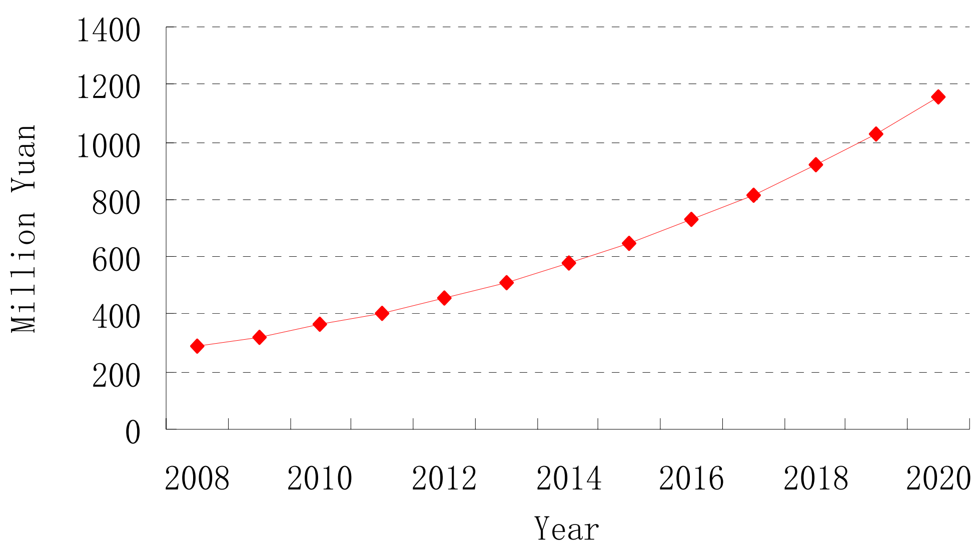

Figure 4-44: Investment Increment Forecast of DAC

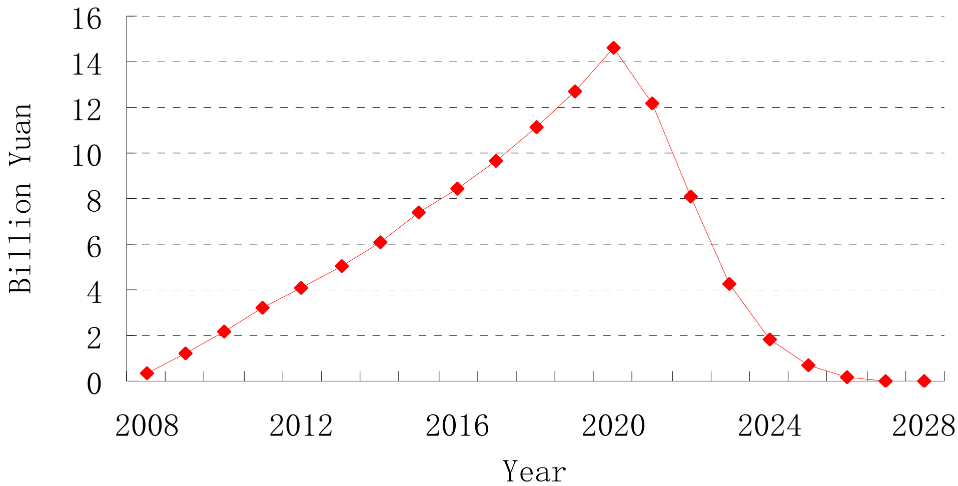

Figure 4-45: Economic Benefit Forecast due to Energy Saving of DAC

By the end of 2020, the net currency value of the investment for small and micro size compressors would be 1.45 billion yuan, and 3.10 billion yuan for large size compressors. But the corresponding energy saving benefit resulting from improving the ventilation fan efficiency standard for those two types of compressors would be 23.24 billion yuan and 30.19 billion yuan. Compared with investment amount, the net profit of project would be 21.80 billion yuan and 27.09 billion yuan respectively. The corresponding ratio between benefit and cost would be 16.08 and 9.74. And investment reclaim period for micro and small size compressor would be about 0.2 years; and for middle and large size compressor would be around 0.7 years.

5 Feasibility analysis and anticipated barriers to implement reach standards

5.1 About standard Development

5.1.1 Capability of standard study and establishment organization

The China National Institute of Standardization (CNIS), the sole state standardization research organization directly under the governance of the General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, is an important standardization and research base in our country that takes important responsibility to develop and exploit Chinese standardization project. Within the Institute, the Resource and Environment Standardization Department undertakes establishment and modification, as well as standardization research in basic comprehensive national standard of energy, resource and environment area, including energy base standardization, energy saving standardization, material saving standardization, water saving standardization, resource comprehensive utilization standardization, environment protection industry standardization and renewable resource standardization, etc. This institute has organized to establish more than 120 national standards about energy saving and energy aspect, including basic standards, management standards, method standards and product standards covering almost all energy saving and energy area. As to the energy efficiency standard, up to now, the Institute has organized to establish and issued 19 energy efficiency standards, including the *Limited values of energy efficiency and evaluating values of energy conservation of centrifugal pump for fresh water*, *Limited values of energy efficiency and evaluating values of energy conservation for fan* and *Limited values of energy efficiency and evaluating values of energy conservation for displacement air compressors* etc. The Institute formed a complete research system of research, development and establishment of energy efficiency standards, mainly represented on:

(1) Established close relation with state administrative bureaus for energy saving

During promoting energy saving standardization, the Institute established very close relation with related state energy saving and standardization administrative departments, such as the Environment & Resource Comprehensive Utilization Bureau of State Development & Reform Commission, the Ministry of Science & Technology, General Administration of Quality

Supervision, Inspection and Quarantine of the People's Republic of China and Standardization Administration of China. And the Institute received support and instruction from those related departments on policy, technology, capital, along with standard plan, draft, issue and implementation; and the institute will continuously acquire support from them during energy saving standardization in the future, especially on establishment and implementation of the energy efficiency standards in order to ensure the smooth process of the work.

(2) Formed an expert network for energy efficiency standard modification

Since 1981, the secretary office of National Standardization Technical Committee for Energy Basis and Management was established in the China Standardization Research Institute all the time. The State Energy Base and Management Standardization Technology Committee was responsible for the technical organization of state energy saving and versatile, basic and comprehensive energy standardization, as well as standardization technology unification in this area. This Committee also dealt with application, approval and report of energy efficiency standards in our country.

Furthermore, the State Energy Base and Management Standardization Technology Committee and China Standardization Research Institute have kept close relation and cooperation with energy experts and experts within fans, pumps and air compressors industry for more than 20 years, including some state level research organizations, such as Shenyang Water Pump Research Institute, Shijiazhuang Impurity Pump Research Institute, Shenyang Fans Research Institute, Shan’xi Fans Corporation Limited Company, Shanghai Fans Manufacturing Factory, the State Compressor Refrigeration Equipment Quality Supervision & Inspection Center, Mechanical Industry Energy Saving Center. These state level fans, pumps and air compressors research organizations and experts in key enterprises could provide technical support on reach energy efficiency standard of these three kinds of important energy-consuming products.

(3) Widely cooperation with international organizations

The China National Institute of Standardization has established close relation with some related international organizations (such as American Energy Foundation, APEC Energy Efficiency Office, American Council for an Energy-Efficient Economy (ACEEE), some energy efficiency standard research organization like LBNL, and some associations of European Union, etc.) and obtained support from them on the national standard establishment for clean water centrifugal pumps, ventilation fans and displacement air compressors; at the same time, it laid a solid foundation for mastering advanced international technologic information, researching and absorbing advanced international experience on energy efficiency standard establishment, finding our gap between the international advanced level and us, improving our energy efficiency standard level, promoting energy efficiency standard research and modification.

(4) Complete research team

After several decades' development, the Resource and Environment Standardization Research Institute under the China National Institute of Standardization has been turned into a key research department within the today's China National Institute of Standardization with a complete research team from only a few people at the very beginning. Among present research personnel in service, 80% of them hold senior engineer technical title, 65% of them hold master or above degrees, about 40% of them own over 10 years working experience in the energy standardization area. The team has accumulated abundant working experience and formed a wide research network.

In recent years, the China National Institute of Standardization grasped the chance of government emphasizing environment protection, recruited many new employees with high education joining the research team. Among them, some graduated from famous research organizations of Chinese Academy of Sciences with doctor's degree, some ever received education in the United States, Great Britain and Canada. Some were graduates with engineering and science background, such as energy, environment, mechanic and computer, as well as law and knowledge property right education. The standard research team achieved unprecedented accomplishment on combining elder, middle-aged and youthful talent structure, or engineering, science and art professional knowledge, as well as talent internationalization, consequently built a stable foundation for promoting standardization and meeting with the international level.

5.1.2 Data and capital availability

(1). Data

Based on long-term standardization work, especially many years study on energy efficiency standards, the research people possess a penetrated understanding of major industrial energy-consuming equipment in our country, such as fans, pumps and air compressors; kept close cooperation and exchanged information with authoritative statistic institution, related associations, research institutes and large-scale state-own enterprises (e.g. the National Information Center, the National Inspection and Test Center, the State Environment Protection Bureau, the Machinery Industry Association, the Energy Research Institute under the State Planning & Reform Commission, etc.) to get authority statistic data and testing data; at the same time, kept long-standing cooperation with large professional survey companies to take advantage of their data on state statistic and testing organizations, thereby guaranteed full understanding of actual Chinese market. In addition, the research team paid attention to collect related international information, especially cooperated and exchanged with international standardization organization and related technology committee, along with experts in some international public welfare establishment and non-public welfare organizations, resulting in good foundation for us to expand data source and improve research level.

However, due to the relative absence of information about energy efficiency of fan, pump and air compressor products, even some developed countries, such as the United States and Japan without energy efficiency standards for these three kinds of products, the indexes reflecting product's energy efficiency are scattered among related product performance standards, or defaulted by involved companies and industries within certain terrain or area, but not being promoted as standards. On the other hand, some large companies have their own energy efficiency indexes, but for the reason of technical confidentiality and knowledge property right, not open to the public. So, it's very difficult to raise feasible technical innovation resolution and make engineering economic analysis for lacking detailed technical information.

(2). Capital

① Support from the state

At present, the state confronts with serious energy shortage and increasingly deteriorated environment, the government attaches greater importance on energy saving, especially the modification work to state energy efficiency standards and economy operation standards of major industrial energy consumed products (e.g. electromotor, fans, pumps, air compressors, etc.). This will promote the energy saving movement in our country. The investment on energy saving area is increased constantly to support related research.

② Support from related international organizations

The energy saving movement focused on energy efficiency standard and labeling are developed all over the world. Whether developed countries or developing countries are seeking a way for sustainable development. Due to the extremely urgent environment protection problems, people are eager to find new ways to save energy and cut down waste discharge. Many international foundations and commonwealth organizations related with energy and environment, even some government organizations and research departments put a lot of capital and material resources into energy saving projects. The capital source for energy efficiency standard research is coming from more and more sources.

③ Support from enterprises

As the main body of market economy and the object of direct action of energy efficiency standards, the companies are not aware of the importance of state energy efficiency standards, and significance that participating into establishment of energy efficiency standard could cut down energy expense greatly, but also clearly see the direction of industrial development and hold market predominance. The reason why no energy efficiency standard marketablization system formed lies on that the companies are not initiative in the establishment and modification of energy efficiency standards.

In recent years, as the increasingly improvement of production technology level, the export quantity of home ventilation fans, centrifugal pumps and displacement air compressors are steadily increased. While actively involving into international trade competition, very few key enterprises started to pay attention to energy efficiency standards and get involved into the standard modification. The changeover for enterprises toward national energy efficiency standard's role and attitude will surely lead the standardization work into a smooth market economy circulation and resolve the capital problem for standard establishment and modification.

5.1.3 Government's attitude

It is a long-run strategic policy for economy and society development in our country and the core of Chinese energy strategy and policy to save energy and utilize resource in a comprehensive way. Our government started to focus on energy saving since 1980s and raised a policy to emphasize energy development and saving equally. In recent years, the demand for energy increased sharply, the energy shortage became worse day by day. To save energy and improve energy utilization efficiency has been put on an unprecedented important place.

During the process of construction a wealthy society, the economy scale of our country would be expanded continuously, and the demand for high energy-consuming industries, such as steel, cement and fertilizer would keep on increasing; energy consumption would increase furthermore. He said:" the energy saving should focus on terminal energy saving, guiding with policy combined with encouraging policies; lay great importance on energy saving of transportation, construction and industry." The energy saving should not be regarded as a measure to relax and cover energy shortage, but a long-run effective system. At the same time, China should adopt international recognized rule on energy price and energy statistic, and strengthen international cooperation.

We must stick to the policy of "Equally emphasizing on energy development and saving, energy saving coming first", aiming at improving energy efficiency and focusing on perfecting regulations and innovation system; making complete plan, perfecting regulations, improving technology, finding key points, strengthening management, and promoting the whole society to save energy effectively. The industrial energy consumption was the majority share accounting for 70% of total energy consumption; the most consumption industries include steel, colored metal, chemical plant, construction materials and petroleum processing. So these industries have the highest saving potential and should be taken as focuses for energy saving. It's necessary to deepen industrial energy saving, increase energy utilization efficiency on construction and motor vehicles from its source. The government organizations should serve as the leading role to guide the whole society to save energy.

5.2 Standard implementation

The minimum allowable stipulated in reach energy efficiency standard for fans, pumps and air compressors are mandatory indexes and lowest requirements for products in home market in future. They are established with sufficient consideration on manufacturers' opinions and suggestions and refer corresponding energy efficiency standards what already issued and still on publicity, at the same time, they combine with technology innovation home and abroad at present.

5.2.1 Manufacturers

It was shown by ad hoc surveys on reach energy efficiency standards for three kinds of major industrial energy-consuming products that most manufacturers attached importance to product technology innovation and went in for improving energy efficiency standard. Tables 5-1 & 5-2 represent comprehensive comparison among the three products' manufacturers.

Table 5-1. Manufactures Attitudes to Technology Innovation

Manufacturers	Extremely	Very Important	Important	Not Important
CCP	65.7%	34.3%	0	0
VF	57.6%	36.4%	6%	0
DAC	57.1%	31%	9.5%	2.4%

Source: Market Survey Report for Pump, Fan and Air Compressor.

Table 5-2: Manufactures Attitudes to Improve Energy Efficiency of Products

Manufacturers	Strongly Support	Support	Not Care	Opposition
CCP	42.9	48.6	8.5	0
VF	21.2	63.6	9.1	6.1
DAC	38.1	47.6	14.3	0

Source: Market Survey Report for Pump, Fan and Air Compressor.

We can see from the data in the table above, the manufacturers of clean water centrifugal pump were most active on recognizing technology innovation and improving product energy efficiency; very minority manufacturers of ventilation fan despised or rejected. However, most (85%) backup the government to establish reach energy efficiency standards as a whole.

In addition, as to the production power of major manufacturers of these three kinds of equipment in our country, our survey showed that all production output reached advanced international level of displacement air compressor, ventilation fan and clean water centrifugal pump exceeded half of total output. The enterprisers who were capable to reach design point efficiency in production exceeded 25%, especially the clean water centrifugal pump manufacturers already reached relative level on high-efficiency product manufacturing. These data sufficiently proved that the manufacturers were able to meet the requirements of reach energy efficiency standard after the next three years technical preparation. And most manufacturers backed the establishment of reach energy efficiency standards. All these factors laid a strong foundation to implement the reach energy efficiency standard before 2008. See Table 5-3 for detailed survey data.

Table 5-3: Manufacturing Level Survey of CCP、VF、DAC in China

Item	Index（%）		
	CCP	VF	DAC
Proportion of manufacturers with at least one product reaching the international top level	68.6	51.5	35.7
Average output proportion of the top level products	53.5	81.1	60.8
Average efficiency of the top level products	77.6	77.6	83.2
Proportion of manufacturers that agree design point efficiency or higher efficiency as the minimum allowable in the product “reach standard”	71.5	69.8	82.9
Proportion of manufacturers that are currently capable of reaching the design point efficiency of products energy efficiency standard	41.7	33.3	24.2

Source: Market Survey Report for Pump, Fan and Air compressor.

5.2.2 Research organizations

(1) Pump Industry

Since 2000, as the rapid development of national economy, the general machinery industry has insisted on market-directed route, promoted product innovation, developed new products through introduction, digest and absorption new technologies and accelerated the technologic advancement of the whole industry. The Shengyang Pump Research Institute (a national design, research & development center of pump products) has developed over one thousand types of pump products in more than 30 series for industries in energy resource, metallurgy, petroleum, chemical, civil engineering and environment protection in recent years. Besides, other backbone enterprises in pump industry, especially some private enterprises developed in recent years dared to introduce advanced design technology from other countries, bring up their own technical team and develop new technology and new products. The technology development in our pump industry is presenting a multivariate situation. Many manufacturers have their own advance production technology and process layout. It’s indicated by survey that 68.6% clean water centrifugal pump manufacturers have at least one product that reaches the advanced international level. The products reached advanced international level of these manufacturers accounted for 53.3% of their total clean water centrifugal pump output.

(2) Fan Industry

In recent years, the fan industry developed well with promoting technology innovation with all effort, adjusting product structure, developing new product actively, and speeded up with technology advancement. They had 1481 types, 346161 sets of new products, winning city-level above technology achievement awards for 89 times. In 2002, they developed 635 types, 12743 sets of new products with new products value up to 1124.95 million yuan, winning city-level above technology achievement awards for 30 times. In 2003, they developed 847 types, 13129 sets of new products with new products value up to 2058.31 million yuan, winning city-level above technology achievement awards for 28 times. The industrial power represented by some backbone enterprises, such as Shenyang Fans Limited Company, Shan’xi Fans Limited Corporation, Shanghai Fans Plant, Tianjin Fans General Factory and Zhejiang Shangfeng Industrial Stock Limited Company, were already strong with progress on centrifugal compressor and axial compressor with high technology contents, and also increasingly improvement on manufacturing technology and process.

(3) Compressor Industry

During 2001-2003, being pushed by the market demand, the development on new product, new process and new technology in compressor industry was more active than the former two years. The development of high pressure and large size reciprocal piston type compressor drove the backbone enterprises within the industry on expansion, perfection and improvement of major product series, with their compressor performance parameters covering even larger area, improvement on reliability and advancement on adoption of new process, new material and new technology. The research organizations and backbone enterprises represented by Xi'an Transportation University Hydro-mechanic and Compressor State Engineering Research Center, Shenyang Gas Compressor Stock Limited Company, Shanghai Compressor Limited Company, Nanjing Compressor Limited Company achieved excellent accomplishments on technology innovation of compressor products and accumulated abundant research experience, consequently provided strong support for the development of energy saving products, guaranteed to establish coordinative testing methods and build necessary testing equipment.

5.2.3 Government

As the national administrative department for promoting energy saving and improving energy efficiency, the Comprehensive Utilization Bureau of Environment & Resource under the State Planning and Reform Commission attached importance on energy efficiency standards and labeling. In the national *Tenth Five Years' Plan for Energy Saving and Resource Utilization*, it's clearly stipulated that the government will formulate and complete product energy efficiency standards of main energy consumption, take steps to establish and implement energy efficiency information labeling system, and continually develop energy saving product authentication as the focus of *Tenth Five Years Plan*. There are 19 energy efficiency standards issued at present, adding up with other standards on modification, these standards have a coverage involving home electric appliance, office equipment, lighting wares and industry & business equipment.

The National Development and Reform Commission published *Middle & Long-term Energy Saving Plan* on November 10th, 2004 to develop and implement mandatory energy saving policy definitely, along with to strengthen power to implement energy saving management including establishing and implementing mandatory reach energy efficiency standards of major industrial energy consumed equipment, establishing supervision system to control product energy efficiency standard implementation, eliminating backward high energy-consuming products and equipment with mandatory measures, editing "Energy Saving Equipment (Products) Catalogue" for fans, water pumps, air compressors, electromotors, etc.

All of these opened a plain road for energy saving of major industrial energy-consuming products in our country in the future from policy aspect.

5.2.4 Users (consumers)

The social development provides larger space for consumers on energy consumption amount, plus with energy price increasing ceaselessly, as a result, consumers spend more and more on energy consumption. Because the fans, pumps and compressors belong to general machinery equipment, they features long time operation, great energy consumption in industrial enterprises. For an enterprise, the electricity expense is a mass cost which takes the second place after employees' salary. Therefore, the consumers of such type industrial products will pay more and more attention to energy consumption expense when purchasing such products. Therefore energy saving products will have much more market space.

5.3 Sequence to establish reach standards

First, standing on the point of energy saving economic benefit, the energy saving of clean water centrifugal pumps will reach 18.4 MMTce in 2020, the energy saving of ventilation fans and displacement air compressors are very close, accordingly 6.65 MMTce and 6.64 MMTce. The products payback periods are all close to half a year.

Second, there are differences among these three types of products' production technical level. We can see from the Table 5-3 that, the manufacturing level for clean water centrifugal pump is relatively higher, over 41% manufacturers are able to reach the indexes in reach energy efficiency standards at present, and 68.6% manufacturers have at least one product reaching the advanced international level. The manufacturing level for air compressor is quite lower, 35.7% manufacturers have advance international level product, only 24.2 manufacturers are able to reach the indexes stipulated in reach energy efficiency standards now.

At length, the sequence will be determined according to the manufacturers' supporting attitude toward energy efficiency standards and emphasis on technology innovation. As the Table 5-1 and Table 5-2 showed, the clean water centrifugal pump manufacturers mostly supported the energy efficiency standards, over 90% manufacturers backup to improve energy efficiency standards, and all manufacturers attach importance to technology innovation. The attitude of ventilation fan and displacement air compressor manufacturers is very close. As to technology innovation, the ventilation fan manufacturers are more active. Considering all aspects and also collecting industry experts' suggestions, the sequence to establish the reach energy efficiency standards for these three kinds of energy-consuming products is proposed as below:

Table 5-4: Recommended Development Order of “Reach Standard”

SN	Evaluation Parameters			Recommended Order
	Benefit	Technology	Attitude	
1	CCP	CCP	CCP	CCP
2	VF/DAC	VF	VF	VF
3	VF/DAC	DAC	DAC	DAC

Source: Market Survey Report for Pump, Fan and Air compressor.

6 Suggestions on policies

6.1 Establish an information center on energy saving

The establishment of product indexes in the reach energy efficiency standards for fans, pumps and air compressors should be based on present manufacturers' production level and ensure it's in advanced level in our country. Based on sufficient understanding the advanced international production and manufacturing technology, it should be done to make engineering economic analysis to series of possible technical resolutions and offer technical support for enterprises' reconstruction process. An information center to collect and manage data and information from home and abroad is necessary to build up to realize the above-mentioned target. The information center may expand to various areas step by step. It should take advantage of modern information transmission technology and all society's force, including some professional organization's database, such as State Statistic Bureau, National Information Center, General Administration of Customs, etc. to timely sort and publish product's energy consumption information, new advanced energy saving technology, new process, new equipment and management experience, and lead enterprises to utilize its potential and improve energy efficiency, at the same time, to provide the related national standard research organizations with powerful platform for collecting complete authorized data information and guarantee standard's objectivity and advancement.

6.2 Set up development and promotion center of energy saving technology

It's estimated by experts that the average efficiency of fan and pump products in our country is 75%, 5% lower than the international level; and the system operating efficiency 20% lower. We also have some gap with international development level on air compressor industry, especially thread rod type and slide type compressor with larger gaps. In recent years, the fan, pump and compressor industry have invested much more efforts on development and introduction of new technology, new process, new equipment, consequently improved the energy saving technology in large scale. However, studying from general view, the investment was still not enough; the innovation ability was weak; the advanced applicable energy saving technology, especially some important common key technology, was not developed well enough. The development and promotion center of energy saving technology should be set up for centralizing excellent research team and providing support and service on applicable energy saving technology for fan, pump and air compressor industry, as well as undertaking publicity activities of energy saving technology.

6.3 Encourage related enterprises' involvement

The study of energy efficiency standard is a very complex system engineering work, the sufficient understanding and support from enterprise, industry, government and whole society is necessary to collect data, test product numerously, prove new technology, along with making and analyzing models. It can not only provide true and complete data, but most importance to form market system of energy efficiency step by step with fan, pump and compressor enterprises' involvement. On the one hand, their involvement can solve the capital shortage problem for establishment and modification of national energy efficiency standard; on the other hand, push the enterprise transfer from passively implementation of product indexes to initiative improvement of product standards and to occupy high-end market. At the same time, their involvement can help to realize the national grand target for energy saving and economy sustainable development.

6.4 Perfect laws and regulations on energy saving

Examining from the implementation view of already published energy efficiency standards, we can find that our national standards were not brought into play enough. The main reason was that, the state has not built and perfected corresponding energy saving law and regulation system matched with related laws, regulations and standards coordinated with the *Saving Energy Law* and resulted continuing circulation and trade in the market of nonstandard energy consumed product, impacted the standard implementation effect and function. The reach energy efficiency standards of fans, pumps and air compressors have something common as general standard. So it should be backed with related national policies, laws and regulations. Government at various levels should establish matching regulations suit with energy efficiency standards based on different local economic situation, to guarantee the implementation of standard vigorously.

6.5 Strengthen government's supervision

Perfect energy saving supervision and management system is precondition to guarantee the implementation of energy efficiency standards and achieving expected result. At present, there are 145 energy saving supervision (technical service) centers all around China, most of them supervise and inspect energy saving entrusted by government. However, generally speaking, most energy saving supervision (technical service) organizations is backward on capability and shortage of information. They can't meet the demand for energy saving course. The state must perfect theses organizations form different aspects to undertake the supervision and management of energy saving; continuously inspect major energy saving projects, honor the products and enterprises with better energy saving effect through multimedia channel to raise enterprises and products' acknowledgement; handle those enterprises in breach of rules seriously; eliminate nonstandard product and make them publicized; realize that all people are active to supervise market, save energy and protect the environment; ensure the implementation of energy saving policies and energy efficiency standards.

6.6 Take advantage of economic measures

The technical improvement of major industrial energy consumed products, such as fan, pump and air compressor is necessarily accompanied with manufacturing cost increase. Many manufacturers are not able or reluctant to adopt new energy saving technology and process for the reason of to huge capital investment. Customers won't buy such product for re higher price. Then, the government's capital support and inspiration policy are very important because it can overcome the barrier of manufacturing cost increase to encourage indecisive manufacturers to reform their technology and process manfully and push customers to choose energy saving products. The most common financial inspiration measures are to offer subsidy to customers, provide manufacturers with compensation, lower down taxation, speedup depreciation, loan and lease out equipment, etc.

The financial inspiration has been proved successful in many countries. It is a method to encourage high-energy efficiency product through paying total or part of extra expenses. The economic preferential policy may appear in many forms, from direct cash discount to increasing tax-free capital limit. For the end-user, the favored value should not be more than extra expense to use high-energy efficiency product.

6.7 Enforce propaganda and training to users

For ordinary customers, the most remarkable characteristic of propaganda information from government and other independent organization is information's justice and authorization. The information maybe very similar with what from manufacturers, but the independent information source is more reliable. The governments at all levels and other independent organizations, such as press publishing house, radio & TV, culture department and related social organizations, should take its advantage to promote energy saving, form strong propaganda voice, expose high energy-consumed, nonstandard industrial products, such as fans, pump and air compressors, give wide publicity to energy saving products and push product market transformation.

There are many ways to provide information (e.g. Catalogue, leaflet, video, software, etc.) or spread information through disc or internet. The following rules can be referred in implementation:

- Must distinguish target group with caution, and determine what activity from them are expected;
- Ensure the selected media has quality level;
- The language and technical detailed expression should meet expected group, and attention should be paid to simplification of technical detail;
- Widely collect manufacturers' comment or hold press release before final publicity (in this way problem may be avoided and gain support from industries);
- Emphasize industry's comment and feedback information.

When the government and other independent organizations give publicity to the energy saving products, one most effective measure is to choose excellent case. The case has similar function to energy saving demonstration. But several points must be attached importance on when using case propaganda:

- The selected case should be representative, easily to promote under normal condition;
- To make target group to realize that the energy saving case may happen to them;
- To select good-reputation company as propaganda tool is most ideal;
- Emphasize personal activity when propaganda, such as signature ceremony;
- The case study should analyze actual problem and possible problem standing on the point of ordinary customers, and ensure the study is just;
- Not to give publicity to product's brand in the case study as possible as you can, or only the manufacturer mentioned in the case will be benefited from the market later on;
- To use kWh or money to emphasize energy saving;
- To evaluate energy saving method and condition clearly;

6.8 Establish demonstration work

The demonstration work should have technical demonstration and representative driving function. A successful demonstration work has outstanding economic benefit and environmental benefit to promote technologic improvement of resource saving and environment protection, increase resource utilization efficiency, strengthen pollution prevention and cure capability and promote continuous development.

The enterprises with large size and strong technical force are normally selected as demonstration work. They have demonstrative and expanding function among the fan, pump and air compressor industry, in favor of promoting whole technical level for saving resource and protecting environment. The projects with better expanding future should be considered preferentially. The active functions of demonstration work can be summarize as below:

- Encourage to improve energy efficiency and to reduce greenhouse gas exhaust directly through a set of comprehensive economic measures. The project itself may be rewarded with great economic and environmental benefit;
- Utilize successful demonstration work, give publicity to demonstration work's effect and significance by various media (internet, TV & Radio broadcast, newspaper, magazine, etc.) through some ways, such as case study and news release; exert the demonstration work's function of guidance and expansion and bring along related technology and industry's development;
- Put the advanced effective practical technology, process and equipment (product) in the demonstration work into the technology, process and equipment (product) list which the state inspire to develop, lead the expansion and utilization of advanced technology, promote combination between demonstration and expansion;
- Improve people's acknowledgement of energy saving and environment protection and management level through economic benefit and productivity increase resulted from improving energy efficiency;
- Permit company to choose their own technical resolution, mobilize companies' initiative, promote technical innovation;
- Develop effective flexible relationship between government and industries.

6.9 Expand implementation channel of standards

Energy efficiency standards can be taken effect through different ways. At present, mandatory laws or regulations, voluntary agreement between government and manufacturers, procurement standards and energy label of products are the most popular measures in supporting the implementation of energy efficiency standards.

- Use laws and regulation to enforce the lowest energy efficiency standards on the product circulating in markets. For some product, the law and regulation are the final measure to eliminate them out of markets;
- Voluntary agreement is a kind of agreement in which manufacturers and customers try to reach same target without corresponding laws and regulations. This measure may have the same effect as laws and regulations. And it is a good method to "soften" market before implementing laws and regulations;
- Procurement standards are product's definition recognized by customer groups. It is used

to describe the features of purchased product for some special application, maybe including energy efficiency classification. Such standards already exist for large range of equipment. Normally those standards focus on safety and operation requirements, but they are very convenient to expand to standard with efficiency.

- Energy efficiency label is a kind of information tag attached on the products or the packet of the products. It is used to represent the products performance such as energy efficiency grade and provide the necessary information for consumers (including all-levels government, enterprises and individuals) in order to help them choose high effienct products when they make a purchase dicision.

To improve a product's energy efficiency, even the transformation of a high-energy efficiency market can't be realized without common effect of multi energy saving measures. As far as a company, as the direct object for effect of all policies and measures, its comment is very important referenced to the establishment and implementation of government's energy saving policies. It is indicated by survey report that, among ten measures shown below, the high-energy consumed product elimination system and energy saving product identification system are most important to manufacturers. See following table for survey results:

Table 6-1: Approach to Improve Energy Utilization Efficiency of Products

Approach		Rate to Be Mentioned		
		CCP	**VF**	**DAC**
1	Improve product efficiency	**62.9%**	63.6%	47.6%
2	Elimination system of high energy-consuming product	**57.1%**	**90.9%**	**54.8%**
3	Attestation system of energy conservation product	**51.4%**	**75.8%**	**78.6%**
4	Economic benefit propagandization of energy conservation product	40.0%	57.6%	35.7%
5	National quality spot-checking	34.3%	**72.7%**	**78.6%**
6	Recommendation catalog of energy conservation product	34.3%	60.6%	47.6%
7	Voluntary protocol between manufacturers	31.4%	51.5%	28.6%
8	Implementation of product energy label system	28.6%	66.7%	35.7%
9	Discharging taxation of energy/CO_2	8.6%	27.3%	11.9%
10	Other	11.6%	6.0%	2.4%

7 Conclusion

To summarize, there is an enormous energy saving potential in Chinese main industry energy-consuming equipments (pumps, fans and air compressors). On the basis of the published (or under publicizing) corresponding energy efficiency standards and fully considering current domestic and oversea manufacturing skills, we suggested using design-point efficiency in the *Limited values of energy efficiency and evaluating values of energy conservation for fan* as the minimum allowable for fan's reach energy efficiency standard; using evaluating values in *Limited values of energy efficiency and evaluating values of energy conservation of centrifugal pump for fresh water* and evaluating values of GB19513-2003 as the minimum allowable in their reach energy efficiency standards. Because we made a special questionnaire to collect comments in representative domestic manufacturers, the indexes provided in this report are not only feasible in products manufacturing technology, but also ratified by Chinese industry associations and government.

According to the generally-used model developed by ACEEE, energy saving potential for those main industry products has been quantified as follows:

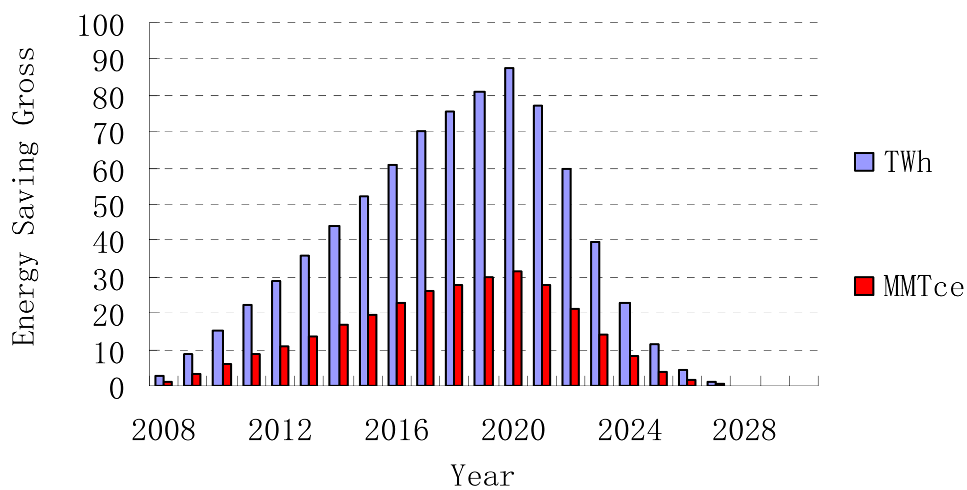

Figure 7-1: Energy Saving Gross Forecast of CCP、VF and DAC

If the reach energy efficiency standards of pumps, fans and air compressors get implementation at the same time, the total energy saving by those types of products will be significantly enormous. Energy saving amount by those three reach energy efficiency standards will be 87.53 TWh，i.e. 31.70 MMTce in 2020 and accumulatively be 585.18 TWh， i.e. 218 MMTce to 2020. Due to the electric saving, the emission reduction of air pollutants will accumulatively reach 165 MMTce for carbon, 2.58 MMTce for nitrogen oxide, 3.70 MMTce for sulfur dioxide and 15.70 for particles. The peak demand of electricity will also be reduced by 311.16 GW.

We got a general understanding of the market situation, manufacturing level of Chinese pumps, fans and air compressors after this feasibility research, meanwhile the minimum allowable of reach energy efficiency standards for those products has been determined. The analysis result of the energy saving model and the specific market investigation strongly proved the necessity of development of those reach energy efficiency standards. Due to the limited financial resources, relative materials collected are not complete, particularly in the aspect of abroad technology innovation. The special market investigation is also focused on the qualitative questions and some quantitative data needed in the model analysis is not included in the questionnaire. In order to develop reasonable reach energy efficiency standards, it is necessary to enlarge and deepen market investigation, conduct products spot check and make a deep communication with technicians to provide advanced, practical scheme for manufacturing process improvement.

8 Appendix

Parameters referenced in the model analysis have been summarized in Table 8-1 as follows:

Table 8-1: Summary of Basic Parameters

Parameter	Value and Unit
T&D Losses	7.55%
Reserve Margin	15%
Electricity Price of Industry Sector	0.56 Yuan/kWh
Discount Rate	7.6%
Heat Rate (2010)	359.6 gce/kWh
Heat Rate (2020)	334.8 gce/kWh
Emission Factor of Electricity for Carbon	267.27 g/kWh
Emission Factor of Electricity for NOx	4.07 g/kWh
Emission Factor of Electricity for SO_2	5.84 g/kWh
Emission Factor of Electricity for PM_{10}	24.80 g/kWh

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