China National Energy Strategy and Policy 2020

Subtitle 10: Policy Research on Energy Research & Development

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Abbreviations

R&D: Research and Development
GDP: Gross Domestic Product
S&T: Science & Technology
IPR: Intellectual Property Rights
GATT: General Agreement on Tariffs and Trade
SCM: Agreement on Subsidies and Countervailing Measures
TRIPS: Trade-related Aspects of Intellectual Property Rights
MNC: Multinational Corporations
CDCL: China's Direct Coal Liquefaction
PDU: Power Distribution Units
SEI: Support of Demonstration Engineering Technology and Techniques Unit R&D
CDM: Clean Development Mechanism
IEA: The International Energy Agency
IPCC: Intergovernmental Panel on Climate Change
IIASA/WEC: International Institute for Applied Systems Analysis/World Energy Council
OECD: Organization for Economic Cooperation and Development
BOT: Build－Operate－Transfer
NPC: National People's Congress
FTE: Full-time Equivalent
CFB: Circulating Fluidized-bed
CFBC: Circulating Fluidized-bed Combustion
PEBC-CC: Pressurized Fluidized-bed Combustion-combined Cycle
IGCC: Integrated Gasification Combined Cycle
CEFR: China Experimental Fast Reactor
PWR: Pressurized Water Reactor
FBR: Fast Breeder Reactor
MER: Market Exchange Rate
PPP: Purchasing Power Parity
UNESCO: The United Nations Educational, Scientific and Cultural Organization
NSTP: National Society of Tax Professionals
PCAST: President's Council of Advisors on Science and Technology
MOST: The Ministry of Science and Technology
PV: Photovoltaic
ICBC: Industrial and Commercial Bank of China
ABC: Agriculture Bank of China
WTO: World Trade Organization
MNC: Multinational Corporation

Executive Summary

This report analyzes and evaluates China's energy R&D policy in the changing international and domestic contexts in the 21st century. It mainly assesses the overall investment and specific allocations of energy R&D resources, the main factors affecting the energy R&D outcome and their application which promotes the advancement of energy technologies. This paper also evaluates the management of various energy R&D programs (from identification of projects to commercialization of R&D results) since the primary goal of the programs is to stimulate the commercialization of R&D results, and thus the policy analysis of energy R&D programs is also presented in this paper.

In line with the functions of responsible government agencies and the national budget, we focus our assessment and analysis of the China's Energy R&D Policy on national science and technology (S&T) programs sponsored by the Ministry of Science and Technology (MOST), in particular, R&D programs such as the National High Technology Research and Development Program (863 Program), National Key Basic Research Program (973 Program), and National Key S&T Projects.

Policy making in the energy field is deemed to be a sort of national action. However, key innovation programs and actions are not well coordinated and organized by the government. A number of programs co-sponsored by more than one government departments, such as the "Clean Vehicle Action Plan" and "Clean Energy Action Plan", rarely represent national purposes and the centralization of distributed resources. Moreover, they have no access to top-level instructions and guidance of national actions. Such actions are not included in this paper.

Previous research on the arena has seldom been carried out in China, and we aim at filling a gap in our S&T policy research area. This is due in large part to the following: 1) the regulation China's energy industry has long been fragmented rather than centralized; 2) R&D programs has not been paid much attention in China's investments and special allocations.

1. Major issues identified in the research:

1.1 China's energy R&D input is too low.

In 2000 china's investment in energy R&D was RMB 5.759 billion and accounted for 6.43% of the national total R&D expenditure and 0.064% of china's GDP, which is much lower than the ratio of energy R&D budget to GDP of most OECD countries. Investment from Chinese government took 10.65% of the overall energy R&D input and accounted for 0.0068% of GDP. China's investment was less in amount than that of most developed countries and reached only 1.8% of Japanese input for the same year.

1.2 China's national energy R&D strategy has not attached adequate importance to energy efficiency technologies.

The 863 Program defined the strategic objectives for the energy technology cluster in early 2002. It concluded that "energy R&D should lay a groundwork for a sustainable, efficient and secure energy supply", and "efficient utilization of clean coal and coal-based liquificated fuel key technology should be improved. The technical and cost barriers towards the large-scale application of nuclear energy and renewable energy should be removed, and novel energy technologies should be developed." This reflects the strategic goals for China's energy R&D.

One major defect of China's energy R&D strategy is that the energy efficiency technology has not been emphasized sufficiently, although a project entitled " major scientific issues regarding energy conservation" was granted in 2000 under the 973 Program, and one of the principle objectives of clean coal technology under the 863 Program is to realize efficient and environmentally sound electricity generation by adopting clean coal technologies. The end use energy efficient technology can also be enhanced in sectors including transportation, manufacturing and construction industries. Climate change caused by greenhouse gas emissions can be effectively mitigated by diffusing advanced energy efficient technologies. In addition, the reliance on imported oil and the economic burden of enterprises and residents for energy consumption can be lessened. The improvement of energy efficiency by adopting innovative technologies is of great significance to raising production efficiency, reducing wastes and lowering costs.

The development of sequestration technology should be deemed to be one of the major projects of Chinese energy R&D in the 21st century. If CO2 could be effectively sequestrated and disposed and utilized effectively, a sustainable development of energy on the basis of rich coal resources will be realized. This is an issue of vital importance to china, which deserves further research.

1.3 Specific energy technology selection is disconnected with the national energy strategy.

The development and decision of the national energy S&T development strategy are made mostly in the Ministry of S&T. Its expert panel consists of the 863 Program energy technology expert committee, the 863 Program expert consulting committee, and the 973 Program expert consulting committee. Project applications are firstly reviewed and selected by technical experts (including a small number of technological economy experts and management experts). Generally, the experts make evaluation of the applications based on their own working experience and knowledge and following the guideline of the Project Office, which no doubt possesses their limitations. Our study indicates that technology selection and formulation of the strategic objective for the 863 Program and the National Program of Key S&T Projects have not been interconnected properly. For example, the projects for coal combustion pollution abatement technology are fragmented and supported by different government departments with little coordination. The selection of the next generation mainstream coal-based electricity generation technologies is also divorced from its strategy objective as mentioned above.

1.4 National S&T programs have fund repetitive energy R&D projects.

The coordination of and cooperation on the selection and management of energy R&D projects under the 863 Program, the 973 Program and National Program of Key S&T Projects have been prominent, since the 863 Program became a regular national S&T program from one of the tenth Five-Year Plan programs. It is difficult to pigeonhole an energy R&D project into basic research, applied basic research, applied research, technological development and commercialization phases, and assign them to the 3 different programs. Energy is a complex science and the R&D process of energy production and utilization technologies is a chain hardly detached. Moreover, it is not only a chain, and the complexity makes it possess features of multi chains crossed. Then repeat and overlapping cannot be avoided when we try to use different programs to manage the R&D of a project in an energy technical sector, and limited resources including capital, technical and management manpower will be wasted.

2. Accomplishments affirmed but to be further strengthened are as follows:

2.1 The investments to energy R&D by the above 3 programs have been stable.

The investment to energy R&D remains approximately 10% within the national S&T program framework and is higher than the ratio of energy R&D input to total national R&D expenditure. Although the input by the national S&T programs takes a major portion (approximately 60%) of the government energy R&D capital investment, the most of which is from central government and the inadequate inputs were provided from other central governmental departments and local governments will, as a result, lead to a low-level government investment to energy R&D.

2.2 Independent R&D capabilities of enterprises in the energy industry have been strengthened.

In the last decade, the ratio of expenses on technology R&D and other technical actions (technical reform, technology import and domestic technology transfer) of large and/or medium-scale enterprises in the energy industry to those in the industries as a whole increased significantly. This indicates that the enterprises' technological actions in the energy industry are more active as compared with those of enterprises within all-field industries.

According to statistic data, technical advancement in the energy industry relies more on external technology (technical reform, technology import and domestic technology trade) comparing with that of all-field industries. When we adopt the ratio of the sum of 'technology import fee' and 'digestion and absorption fee' to the sum of 'technology import fee' and 'digestion and absorption fee' and 'domestic technology trade cost' and 'technology R&D expense' to measure the degree of reliance of Chinese enterprises' technical advancement on overseas technologies, the degree of large and/or medium-sized enterprises in the energy industry is much lower against that of enterprises within all-field industries. Further, it has been declined during the last decade.

Currently, government capital and bank loan account for 4% and 10% respectively of the self-raised fund for S&T activities by the large and/or medium-sized enterprises, and the remain is from enterprises' own capital.

The data analysis indicates input to R&D projects for decreasing energy consumption constitutes only a 2% share of the enterprises' R&D expenditure that accounts for 53.58% of the total investment for national R&D projects. The ignorance of the R&D of efficiency improving projects is another feature of S&T activities of enterprises in the Chinese energy industry currently.

2.3 The development of advanced energy technology is encouraged by China's accession to WTO.

We focus our making a study of china's energy R&D on the 863 Program, the 973 Program and National Program of Key S&T Projects (also a little bit to National Natural Science Foundation, National Key Lab Construction Project Programs, National Mega S&T Projects, National Engineering Research Center Projects and Engineering Technology Research Center Construction Projects and etc.). There is no conflict between our government's fund to these S&T actions and prescriptions of WTO's "Agreement on Subsidies & Countervailing Measures (SCM) ".

During the internationally cooperation process in the 863 Program since the implementation of the 10th Five-Year Plan, cooperation and communication in various forms that combine independent R&D with technology import and assimilation and absorption have been further encouraged. Special fund for international cooperation has been particularly established. Following the "Agreement on S&T Cooperation between China and EU", the MOST opened some research projects under the 973 Program to OECD and one of which has been initiated. Most projects under the 973 Program have formed a broad and deep communication and cooperation relationship with worldwide countries in varying degrees.

We particularly investigated the direct coal liquefaction key technique project under the clean coal technical theme in the energy field set in the 863 Program. It is a project cooperating with Shenhua Group Ltd. importation of AXENS company's direct coal liquefaction technique demo production line, and this is the first time to establish technology import supporting R&D project in the energy field under the national high technology development programs.

With the assistance of the highly advanced technology import demo project, supportive system platforms for independently created technologies have been developed, and R&D improving key techniques (such as solvent hydrogenation process and high efficiency catalyst) have implemented, thus the industrialization of advanced energy technology has been promoted. The project aims to develop a novel Chinese Direct Coal Liquefaction (CDCL) technique, and achieve a CDCL technique package based on the PDU of 6 ton per day. The CDCL technique was defined and a patent application referring to it was filed correspondingly. More patent applications are being prepared and final achievements may be applied in consequent production lines (the 2nd and 3rd lines) in Shenhua First Phase Project. Undoubtedly, this is a novel mode for technological innovation deserved a study in depth.

3. The main suggestion of this search:

3.1 Enlarging energy R&D investment

- To increase national R&D investment, especially increase the share of energy R&D expenditure on national R&D investment, in order to resolve the macro problem of the low input of energy R&D. At meanwhile, energy R&D funding from government should be increased. The share of energy R&D to national R&D spending should increase from 6.4% in 2000 to 7% in 2010 and to 8% gradually in 2020. The share of government energy R&D spending to total government R&D budget should increase from 1.9% in 2000, to 3% in 2010 and to 4% ～5% in 2020.

- Within the funding of national S&T programs, appropriate ratio should also be set up for energy R&D. In the specific S&T program, it is necessary to reasonably arrange the funding for energy R&D.

- In order to make the most use of the limited resources, government should identify a limited number of more focused goals, pull key advantage resources, and resolve the most critical technology in energy R&D in the formulation and implementation of national S&T programs. The project selection and funding in S&T programs should satisfy the demand of strategic goals of national energy policy.

- To form partnerships between government and industry, and partnerships among enterprises on the bridge of the projects of national S&T programs. Risk and benefit sharing mechanisms should be introduced to carry out capital-intensive, time-consuming, and high-risk R&D projects. It is recommended all demonstration engineering projects adopt this implementation modality.

- To make full use of the international resources, and expand the funding sources for national R&D activities. Since china's accession to WTO, China has been facing more opportunities to participate in international S&T cooperation. On the one hand, researchers and R&D institutes should be further encouraged to take active part in international energy R&D cooperation positively. We suggest the government set up a special fund to support international cooperation in national S&T programs. On the other hand, multinational corporations should be encouraged to establish their own energy R&D centers China in order to engage in R&D activities on energy technologies.

3.2 Improvement of government management

The Chinese government should formulate national energy supply and consumption strategy, and national energy R&D strategy to meet the national economy and social development on the base of the forecast in energy demand. The formulation of energy R&D strategy should be based on the regular technology foresight practice to identify priorities and select national critical technologies.

Regarding the national S&T program management, government function should be shifted directly from operating S&T programs to taking charge of project selection and fund allocation, participating evaluation and assessment, and consigning the implementation process management to intermediary agencies. In that way, it is helpful for government not only to play a leading role in implementation of strategy, but also to avoid to getting into concrete affairs rather than high-level coordination and management.

The restructuring of research institutes in the past years has greatly promoted the process of R&D institutes transform to technology-based firms. R&D institutes transferring to technology-based firms or merged into enterprises is the effective way to enhance enterprises' R&D capability and accelerate commercialization and industrialization of R&D results. Government should vigorously encourage energy enterprises to establish R&D centers within them. National S&T programs provide the linkage and stage for the cooperation research between firms and research institutes. The development and enlargement of homemade FBCC is one of the best examples. In the future, government should play a greater role on introduction and promotion of close linkage between R&D institutes and firms.

A comprehensive and coordinated mechanism on energy R&D should be set up between government sectors and within a ministry, including formulation of S&T development plan and industry development plan, exchange and share of information, and utilization and diffusion of R&D results.

Specific suggestions include: to set up the combined appraising system of industry policy and S&T policy on energy; to set up a uniform energy S&T expertise group under different S&T programs, whereas in the past there were respective expertise group under different S&T programs; to appoint an administrative official responsible for all energy S&T programs who coordinate with all other S&T officials from different departments of MOST.

3.3 Promoting the development of intermediary institutions

Industrial associations, which consider it as their major responsibility to bridge enterprises and government with information exchange and conduct academic activities and technology service, and other intermediary organizations should develop and enhance internal organizational operations within more broad of scope when the government sectors reform and China accesses to WTO. Facing the challenge of international intellectual property rights (IPR) competition, one of the important tasks for the intermediary organizations is to coordinate member firms' behavior, resolve common problem for the firms within their sector, and formulate the sector's overall IPR planning of for the interests of all firms within the sector. Industrial associations should play an important role on promoting government to invest more money on protection of IPRs and development of IPR information networks and support in applying international patents for key technologies. It is also needed to set up important coordination mechanisms and play industrial association role in settlement of internal dispute and disagreement.

Industrial associations should have played position in energy innovation system.

All government actors, enterprises and R&D institutes should understand well with the important roles industrial associations play and make full use of them.

As an intermediary S&T institution, the Innovation Foundation for Medium-scale Firms has been playing a positive role in promotion of energy SMEs development and energy saving technology development. Further funding for this program in the new circumstances will be worthwhile.

3.4 Further development of the market function

After china's accession to WTO, China's energy industry will be more and more influenced by the market-based economic system, and the role of market on resource allocations will be continuously reinforced. Establishment of common market regulations compliant with WTO and good order of market on the legal system is great helpful for energy technology flow and R&D investment to energy firms. Energy R&D policy-making must consider well how to play the market function, and how to overcome the obstacles to energy R&D through the market mechanism. Government should pay attention to nurture the market for new energy. It can introduce the formation and development of new energy market. Furthermore, government guidelines can push firms to invest more in clean energy R&D in a market way that is by market pull and inner motivation of firms rather than government push.

3.5 Enhancement of energy strategy research

The establishment of energy development strategy should adapt to the needs of constructing middle-class family society completely. R&D and innovation of energy technology is very critical to meet such huge primary energy demand as 2.5～3.3 billion tce would be consumable in the year of 2020.

The government should insist on conducting technology foresight research on which national key technologies and priorities of energy R&D are selected.

High attention should be paid to R&D of technologies to increase energy efficiency of the end-use consuming sectors such as transportation, industry and construction sectors, and technologies of clean energy producing and consuming including sequestration technology.

It is the international energy R&D trends to develop clean energy technology which is also the practical demand for establishing completely the middle-class family community and sustainable development.

The clean energy technology can be defined as the advanced, environmentally friendly energy production and end-use technologies. One of the central objectives of China's energy R&D should be to develop technologies with indigenous IPRs and suitable to China's situation. Development of clean energy technology should be one of key options for China's energy strategy and S&T strategy. This report recommends continuous investment and policy support should be enhanced to clean and efficient energy R&D in national S&T programs.

Policy Research on Energy Research & Development

Energy is a lifeline for national economy, especially for China in the process of escalating industrialization. Technological innovation in the energy field is critical to economic prosperity, environmental improvement, and national security. As compared to other sectors, energy development rely more on R&D technology selection and input, because of its high costs, long period of innovation, and its vital function of public welfare and foundation. In short, in the face of the challenges of China's accession to WTO and global climate change, research on China's energy R&D status quo, R&D inputs, energy R&D programs and policies constitutes a vital task to study China's energy strategy and science and technology (S&T) development strategy.

1. Background

1.1. Impact of China's accession to WTO on energy R&D

After China's accession to WTO, development of the energy industry must not only satisfy the needs of national economy, but also face the increasingly fierce competition in the international marketplace. Under the dual pressures, China's energy industry can further develop only by accelerating the S&T progress. We should adjust existing relevant policies with regard to energy R&D, which are for the most part deeply rooted in the centrally planning economy.

1.1.1. Challenges imposed by the WTO regulations to China's energy R&D

In accordance with the WTO regulations, China will further open its market, and China's energy industry with low production efficiency will face more severe challenge and competition. At the same time, China's energy demand and supply structure will change also, because the traditional energy consumption structure cannot meet the high-speed progress of national economy. And it is very impendent to upgrade the traditional energy technology. Regulations of WTO related to energy industry take sustainable development as its basic principle, referring to the developed countries, which is very critical to developing countries as China. So China's energy R&D will face huge challenges henceforth. It embodies following facets:

Most of WTO main regulations have something to do with national S&T programs and R&D work, such as the Non-discriminatory principle (Most-favored Nation Treatment, National Treatment), Sufficient Market Accession Principle (customs duties decrease, non-customs barrier abolishment), the Fair Trade principle (anti-dumping, anti-subsidy etc.), Trade Policy Unification and Transparency Principle, IPR Protection Enhancement and Consultation Issue Settlement Principle and so on.

National Treatment Principle and indigenous policy

National Treatment Principle is one of WTO (especially GATT (General Agreement on Tariffs and Trade)) essential regulations. China has committed to abide by the investment convention about trade and abolish foreign exchange balance requirement, trade balance requirement, local contents requirement etc. For a long time, a number of industries have practiced indigenisation policy, through establishing policy and laws stipulating some premises of examination and approval of Chinese-foreign joint projects or internal projects, such as encouraging foreign enterprises to transfer certain technologies and purchase indigenous equipments in some proportion. Different with WTO indigenous treatment principle, these policies must be carefully examined and adjusted.

For example, about nuclear power development, China has been long adopting the policy of “promoting indigenisation on the basis of both self-dependence and international collaboration”. In accordance with the WTO regulations, it is inappropriate for the Chinese government to make mandatory policies and regulations on the minimum requirement on domestic manufacturing of nuclear power equipment.

Reduction and exemption of customs duties

China’s customs duties decrease and non-customs barrier abolishment is one of main promises of WTO accession. China has consented to reduce customs’ total level year after year from 2001, 14%. In 2005 the total level will be reduced to about 10% and customs of industrial products will decrease from 13% to 9.3%.

For example, China has consented to reduce radioisotope customs from 7% to 5.5%, such as natural uranium,enriched uranium,heavy water and other radioactive isotopes. For nuclear reactor and non-irradiated fuel element, China has promised its customs is 2%.

Technical barriers

Criterion issue has been beyond domestic technology and economy category, and become the precondition of product internationalization. Without support of international criterion and foreign advanced criterion, it will be very hard for China to expand export-oriented economy. Vigorously pull adoption of international criterion has been regarded as important technology approach to abolishing overseas technical barriers and accelerating external trade.

Until 2001, among the 19744 national criteria China has promulgated, there are 8621 adopting international criteria or international advanced criteria, and its ratio adopted from international standard is 43.7%. The ratio adopted from international standard of Petroleum industry is 50%. According to China's promise, within 5 years after accession to WTO, the ratio adopted from international standard of China technology regulations will be increased 10% in China.

Subsidies and countervailing measures

WTO Subsidies and Countervailing Measures Conventions (SCM Conventions) stipulate measures about subsidies and countervailing definitely. Conventions prescribe subsidies as special subsidies and non-special subsidies, concretely classified as: inhibitive subsidies (export subsidies, import displace subsidies), litigant and illegal subsidies. China makes promise to abolish export and import displacement subsidies, and to treat subsidies supported with state-owned enterprises as special subsidies prescribed by SCM Conventions.

Noticeably, according to SCM Conventions,it will become illegitimate subsidies if "assistance to R&D activities of enterprises, or assistance to R&D activities taken by enterprises and higher education institution or research institution, does not exceed 75% of industry research cost or 50% of development activity cost before competition". We must analyze concerned national S&T programs and projects in terms of these conventions. Moreover, S&T input to higher education institution or research institution (unrelated to enterprises) is beyond this limit. Chinese government has consented to gradually abolish subsidies of some loss-making state-owned enterprises that offered by central government.

As national strategic industry, energy directly relates to development of state security and national economy, and it is necessary for government to support variously. On the ground of accession to WTO, we should seriously study whether the various input or support of government accord with regulations of WTO.

Intellectual property rights protection

Trade-related Aspects of Intellectual Property Rights (TRIPS) is the one of three WTO key agreements, and to strengthen the protection of intellectual property rights (IPRs) is one of WTO fundamental goals, which has solved some long-standing problems, for instance, in the past IPRs conventions can only rely on domestic legislation, lacking any international supervision mechanism, consistent criteria, and strict protection. In a number of major fields, patents we applied are much fewer than those overseas competitors did, through which we can know how much it is serious. So we must strengthen the sense of IPRs protection, and indeed enhance autonomous innovative competences and core competitive capabilities. Now China’s existing laws about IPRs completely conform to the requirements of TRIPS, but the stimulation mechanism about ascription and interests distribution of IPRs still need to be enhanced and perfected.

Competition for talented person

After accession to WTO, China will face severe fight against Multinational Corporations (MNC) for “primal resources” -- talented person,focusing on competition of high-tech person. In terms of the WTO regulations, multinational regulation, say, “locus principle”, “requirement of canceling indigenous element “and “indigenization trade”, will largely weaken company international background. Obviously, it will actively impact on China’s S&T development, further aggravate competition in domestic person of good quality and affect the stability of S&T groups to some extent.

1.1.2. Increase in competitive pressure

It is generally believed that the advantage of developing country to develop is rich resources and low-priced labor force. After accession to WTO, China’s energy industry needs to face internal and external market at the same time. For low energy utilization efficiency, low technology content and continual high product cost, China’s energy industry is at a disadvantage in the furious international competition. Only by improving market efficiency resorting to national S&T progress, can we win in the international market.

1.2. New opportunities for China’s energy R&D

It is irreversible that China enters into economic globalization. Accession to WTO will bring good opportunities of our energy R&D. It embodies aspects as follows:

1.2.1. Reinforcing effect of market on R&D decision-making

Economic globalization results in WTO, and demands every country and region to open up market economy. It also requires every resource to be distributed impartially and rationally all over the world under the marker competition mechanism. The importance of energy industry determines, in the gradual reform progress, its development and investment will continually be decided mainly by plan. Whereas market factor will plays its role in energy decision-making more and more.

Firstly, international market will be more open to China, which will make China's internal market more open. On the one hand, as WTO demand China to open service market gradually, China will mend its pace to set up finance, labor force, technology and information market, and then mature its production element market. On the other hand, WTO has established a set of unified market regulation and good market order on the basic of legal system. This will make for orderly flow of energy technology, help energy enterprises to gain R&D financing from more channel, to finally increase energy R&D input, and improve utilization efficiency of energy R&D financing.

Secondly, following the open and maturity of market, in the industry development course our government will adopt more market measures to lay a foundation of R&D policy decision mechanism formed by enterprises. The mode that government gives financial assistance to energy R&D through national programs and projects will gradually be changed to that enterprises associate with government and that enterprises autonomously develop energy R&D.

1.2.2. Gradually removing the barriers towards energy technology cooperation and exchange

After the accession of WTO, China would enjoy some preferential external trade polities, such as most-favored nation treatment, "general preferential" treatment, gradual customs duties decrease and other attentions developing country enjoyed. So when we import technologies, say energy technology, the opportunity and range of choice will be more and more and the cost will be less and less, especially when we import high and new technologies such as new energy technology, we will enjoy more convenience.

Reducing import customs duties can cut down enterprise's technology import cost and total manufacture cost, thereby increase efficiency and core competitive capabilities. At the same time, this will make product price decline and be advantage to consumers.

On the premise of legal guarantee of IPRs, every country could feel easy to transfer technology to China and obtain relevant economic rewards, which will bring first-class industry technology into China to create good condition.

After accessing to WTO, China's import means are being improved further, for instance, equipment trade, license trade, joint venture trade and cooperative business operation, international BOT mode, technology consultation, joint production, franchised business operation. Our energy enterprises can choose rational import way according to requirement to gain advanced technology at a low price and promote technology import efficiency.

Facing international market, China enjoys more channel and convenience in financing and foreign finance organizations will transfer its short-term speculative action to long-term investment in course of accession to China market. Because, to most energy projects, the cycle is long and investment is heavy, the broadening of financing and import bring new opportunity to China's energy R&D.

China, after accession to WTO, enjoys Non-discriminatory Treatment, Most-favored Treatment, National Treatment and other preferential treatment to developing countries, so China could be fairly treated as importing high technology from other WTO member countries. In a word, we should make the best of this opportunity to improve the energy technology level.

1.2.3. Integration of independent R&D and technology importation

The relation of technology import and autonomous R&D, to developing countries, may be an eternal issue. The previous discussions about this question are frequently isolated and opposite. In fact after China's reform and opening up, especially since China's accession to WTO, because strengthening of IPR protection, China establishes not only domestic legislations but also international supervision mechanism, moreover standards are unified day by day and protection is improved more and more. This makes for technology import and accelerates process of autonomous R&D. The coal direct liquefaction under the 863 Program is a good example.

To mach up the product line construction of coal direct liquefaction imported by Shenhua Group Corporation limited from America, the 863 Program has set up the project of coal direct liquefaction key technologies. The project comprises the following subprojects that is clearly divided of labor and responsibility and collaborate mutually: optimization of demonstration engineering key technologies and R&D of China's direct coal liquefaction (CDCL) techniques PDU installation (Shenhua group Corporation limited), support of Shenhua coal direct liquefaction demonstration engineering technology and new technical arts R&D (China Coal Research Institute), optimization of coal liquefaction technology by adding hydrogen and new technical arts and activators R&D (China petroleum & chemical Research Institute), support of demonstration engineering technology and techniques unit R&D (SEI). The previous research and research on coal direct liquefaction is fulfilled by America HTI Corporation, and the general technology import contractor of Shenhua Group Corporation limited is America AXENS Corporation.

The open policy establishment of the 863 Program makes the project, to assort with importing international technology, give support to the R&D of demonstration technology. It also makes the project research on innovative key technology to optimize techniques. For new CDCL technical arts with autonomous intellectual property, developing CDCL techniques unit on the base of 6 ton per day PDU, China has put forward the conception and patent application of coal direct liquefaction. Its last research result may apply to the following product line (the second and third) of Shenhua project. The patents applying are the follows: “an activator used in adding hydrogen process of petroleum product and coal liquefaction and its manufacture approach”, “a kind of technical arts of diesel oil with high-cetane number from direct coal liquefaction” and “a combined technical arts of maximum coal oil liquefying transformation”.

Tying in importing engineering technology and developing technology support platform will help to study and develop key technology (for example, technical arts of hydrogen solvent and high efficient activator), to promote new technology and techniques with autonomous intellectual property, and to accelerate commercialization of new technology. Obviously, after China’s accession to WTO, it is a new mode of technology innovation for us to seriously study.

1.3. Challenges of the global climate change

1.3.1. Effects of sustainable development on energy industry evolution

Adequate and efficient energy supply is the basic of national economy development, state security and society sustainability. Energy will not only affect a country’s interior, but also global economy and politics. Energy product and utilization effect environment and climate change, which make the energy and climate become the focus of international issue. In terms of Climate Change Framework treaty passed by United Nations environment and development convention in 1992, Kyoto, capital of Japan, held Global Climate Change Conference in Dec 1997. Until Mar 1999, there are 83 countries assigned the Kyoto Climate Change Convention, which has bring great impact and significant effect on energy product, utilization and its S&T development.

36 countries that assume reducing and restricting CO_2 emission in the Kyoto Protocol (including west developed countries and USSR) will averagely reduce 4% between 2008 and 2012 (compared with emission in 1990, America, Japan, and Western Europe will respectively reduce 7%, 6%, 8%). In July 2001, at the Bonn Global Climate Change Conventions Session, except for America, 177 countries reach an agreement on the Kyoto Protocol on Climate Change.

The influence of Kyoto Climate Change Convention on energy utilization and selection is very immense and significant. In the short term, it is, in demand side, the technology of low-pollution fuel development and utilization and clear energy transformation; it is, in supply side, the technology of efficiency improvement. In the long term, it is uncreated technology or that still being in the initial stage of business, including: low or zero emission energy (renewable energy, hydrogen energy, advanced nuclear energy), low consumption of unit product technology (traffic transport, illumination), and sequestration technology.

Of course, Kyoto Climate Change Conventions has influence not only on technology. According to conventions, countries of accessory will practice trade of CO_2 emission right and united appointment one another, and between Annex 1 countries and other countries, there will set up clean development mechanism (CDM), namely, advanced countries offer developing countries finance and technology support and its CO_2 reduction share will reckon in CO_2 emission reduction of developing countries.

In August 2002, the World Summit on Sustainable Development was held in Johannesburg of South Africa. Deputies form 191 countries attended the meeting, including governmental deputies, private enterprise folk association organized by in non-governmental circles and academic research group. This meeting adopted passed Programme of Action and Johannesburg Declaration.

Johannesburg Declaration on Sustainable Development embodies six parts. The first part, “from our origin to the future”, affirm the promise of sustainable development and our responsibilities to the earth and future. Especially it definitely put forward three backbone of sustainable development: economy development, society development and environment development, which depend on each other and strengthen mutually. The second part, “form Stockholm to Rio de Janeiro and to Johannesburg”, summarize the 30 years long progress of sustainable development. The third part list “challenges we are facing”, for instance, poverty, the great disparity between the rich and the poor, exacerbation of environment, globalization and imperfect system. The pronouncement consents to sustainable development in fourth part. The “multilateralism” stressing international cooperation is emphasized in the fifth part. The last part focusing on “promoting realization of sustainable development” aims to “guarantee the common hope of sustainable development”.

Considering the two types of its results, global head summit meeting about sustainable development aims at practice. “Type I” result is routine international conventions reached by negotiation. “Type II” result is partnership, which is an innovation. And as we can see, the two types result has composed a new sustainable development framework.

1.3.2. World energy outlook and energy R&D trend

We quote the forecast released at the end of 2000 by IEA, authoritative international energy medium-term forecast organization: world energy demand between 1997 and 2020 will increase 57% and primary energy demand divided by GDP will fall on average by 1.1% per year. Primary energy structure will not change dramatically. The proportion in 1997 and 2020 are as follows: oil is 40%/40%, natural gas is 22% /26%, coal is 26% /24%, nuclear power is 7%/5%, waterpower is 3%/2% and other renewable energy is 2%/3% (See Table 1-1).

Table 1- 1. Proportion of world primary energy demand (IEA at the end of 2000)

Year	Oil	Natural gas	Coal	Nuclear power	Hydro -power	Recycling energy
1997	40%	22%	26 %	7 %	3 %	2 %
2020	40%	26%	24 %	5 %	2 %	3 %

However the forecasts from two authoritative organizations on world energy outlook in 2050 were quite different. In 2000, IPCC forecasted that world energy demand in 2050 will increase to 2~3.6 times of 2000, up to 26680~43450Mtce. From high growth scenario (See Table 2-1), the proportion of coal, oil, natural gas, nuclear power and renewable energy are 12.2%, 13.1%, 30.1%, 22.9% and 21.7% respectively. From low growth scenario, they are 7.8%, 12.2%, 20.7%, 24.5% and 13.3% respectively. From the IPCC high growth scenario, the sequence of primary energy contributions from high to low is natural gas, nuclear power, renewable energy, oil, and coal. While from IPCC low growth scenario, the sequence is nuclear power, natural gas, recyclable energy, oil and coal. This result is far from that of IIASA/WEC forecasted in 1995. Its basic scheme shows that world primary energy demand will amount to 28300 Mtce in 2050, among which coal, oil, natural gas, nuclear power and renewable energy account for 20.7%, 19.8%, 22.7%, 13.6% and 22.0% respectively.

Table 1- 2. Proportion of world primary energy demand in 2050 (forecasted by IPCC and IIASA/WEC)

Energy / Resource		Oil	Natural gas	Coal	Nuclear power	Recycle energy
IPCC (forecasted in 2000)	High growth scenario	13.1%	30.1%	12.2%	22.9%	21.7%
	Low growth scenario	12.2%	20.7%	7.8%	24.5%	13.3%

IIASA/WEC (forecasted in 1995)	19.8%	22.7%	20.7%	13.6%	22.0%

Current forecast indicates that in terms of primary energy structure, coal and oil will decrease gradually while natural gas, renewable energy, and nuclear power will play an important role in the future. It is the general developing tendency of world primary energy utility. The development of energy S&T just conforms to the trend.

Current world energy development tendency indicates it is transforming to renewable energy system at high speed. Between 1990 and 1999, total installed capacity of world wind power, geothermal power and waterpower increased annually by 24.2%, 4.3% and 1.8% respectively. At the same time, capacity of photovoltaic cell increased by 24.2% per year. Whereas fossil fuels increased relatively slow. Natural gas, oil and coal increased by 1.9%, 0.8% and –0.5% annually. During this period, total installed capacity of nuclear power increased only by 0.5% per year. However, the current proportion of renewable energy is low, so the interim will last long.

The case that energy R&D in OECD countries inclines to clean energy indicates these countries are taking great actions to solve greenhouse gases emission problem caused from the energy sector. IPCC released the 3^{rd} appraisement report in 2000. It emphasized the graveness of climate change. At the same time, the report drew a explicit and scientific conclusion: climate change is the result of human activities; social economy and natural system are weak compared with climate change; it is possible to alleviate climate change and the expenditure mainly lies on the choice of policy. The facts mentioned above are the general background of current world energy R&D development.

1.4. Energy demand of China in 2020

1.4.1. Energy demand of China in 2020

China is not only the most populous country in the world, but also one of the largest energy producers and consumers. The energy demand of China is influenced by multi-factors, such as socio-economic development, the evolution of economic structure, technological progress, energy conservation policy and energy resource mix, etc. In the long run, it is agreed that the primary factor of China’s energy demand remains the socio-economic development at a continuously high speed. The 16th Congress of the Chinese Communist Party assembly put forward several goals, such as building the well-off society at higher level in the interests of the whole population, GDP striving to quadruple more than 2000 by 2020 and realizing basically industrialization by 2020 on the basis of optimizing the structure and increasing the benefit. The realization of above-mentioned goals requires sufficient energy supply.

So there is very high request to the energy correspondingly particularly.

Building the well-off society in an all-round way means that more and more people in the countryside will enter the city and urbanization process will greatly accelerate. It is estimated more than 56% of the population will live on the town having modern economy, culture life and energy service by 2020. Urbanization process will promote the service trade, the communication and transportation business. On the following 20 years, the development speed of the tertiary industry is hopeful to exceed secondary industry and the proportion of the tertiary industry within GDP may rise to more than 40% by 2020. Commerce, culture and education, scientific research, hygiene, sports, amusement, travel, finance and all kinds of government administration will get considerable development. The corresponding building and construction area increase at double. The per capita living space of urban and rural residents will be improved further. Heating, air conditioner, hot water and so on will be popularized basically. And comfortable degree has obvious improvement. With the urban income level of resident unceasingly heightening, more and more little automobiles by family oneself use enter family. Traditional biomass energy such as firewood and stalks consumed by rural resident will be substituted progressively by the goods energy too. It is estimated that the growth rate of energy used for the tertiary industry and resident directly living may exceed the growth rate of the energy used for industrial by 2020. And it is clean, convenient and high-quality energy, such as the electricity, gas and liquid fuel. All these put forward high request to energy supply.

By 2020 China will realize industrialization basically, which means that the scale of industrial production should be still expanded continuously. The secondary industry on behalf of industrial production will go on and become the protagonist of economic growth in the future. It is estimated that the proportion of the secondary industry accounting for GDP will continue keeping about 50% by 2020. Industrial department is the economic department whose energy intensity is supreme. During the following 20 years, industrial department in China still needs more energy supply.

Studying from current situation of China, our economic development has not realized industrialization yet. There are still 900 million peasants living in the rural area. Industrialized course and urbanization process are analogous to the distance. To reach the developing goal, that is to say, to build the well-off society in an all-round way which is put forward on the 16th NPC session, the per capita consumption of energy should reach 11 tce according to the consumption level of the U.S. The per capita consumption of energy needs 5.2 tce according to the average level of the countries of Organization for Economic Cooperation and Development (OECD). If the per capita consumption of energy can reach the highest level of consumptions in Japan, it exceeds 4 tce as well.

China must take the new pathway of industrialization through the S&T progress, but by 2020, primary energy demand in China will still reach 2.5~3.3 btce. Therefore in China the future of energy development, especially energy supply, will face the very severe challenges.

1.4.2. Impact of the energy demand on energy R&D

China will become the biggest economic entity and exported country in the world and the total population will become 1,400 million in 2020, which comes into being the lasting enormous demand for energy consumption. So our country must adjust highly self-sufficient internally oriented energy strategy and must be on the base of the actual circumstance at home and meet the needs of the world in order to come about the market strategic change and the new-type energy development, which is basic self-sufficiency and promotion trade.

(1) To implement the sustainable energy development strategy, which has characteristics of increasing efficiency, optimizing the structure of energy and strengthening environment protection. In the following 20 years, it is estimated that the intensity of energy consumption (energy intensity per unit GDP) of our country drops by 2.3% ~ 3.7% per year. This will be less than 1.1%, which is the average annual descent rate of global energy consumption when it comes greatly. To implement strategy, it is necessary to make national strategic objective of the energy structural adjustment and make plans about petroleum, natural gas, electricity and renewable energy. Judging by the second sub-subject, whose item is to analyze Chinese energy demand scene, in which the economy of our country and the domestic and international states of the natural gas, hydropower, nuclear power and other renewable energy are analyzed. Our country should change the current energy consumption structure relying mainly on coal and increase the production and consumption of petroleum, natural gas, hydropower and nuclear power, and expand the proportion of the renewable energy progressively.

The strategic objective of energy R&D will be made and be adjusted according to above-mentioned. Energy R&D at production and supply side should develop clean coal-fired power generation technology, the production technology of coal-based liquid fuel, the exploitation technology of natural gas and petroleum, nuclear power technology, renewable energy technology, etc.

(2) To strengthen energy-conservation, to increase efficiency and to improve the status between supply and demand of energy. After economy enter the last industrialized stage, the energy- consuming elastic coefficient in some developed country is generally smaller than 1. When the economic growth is relatively fast, elastic coefficient is relatively higher. If the rate between economic growth and energy consumption of China keeps 1, the total primary energy demand of China will be up to 6 btce in 2020. In the future if China is only according to 1.1%, the level of the average annual energy-conservation of the world in the past 30 years to improve

efficiency, the average annual growth rate of energy demand will be more than 6.0% and the energy total demand will reach about 4,800 mtce in 2020. So to lead sustainable increasing of Chinese future energy demand, it is extremely important to strengthen energy-conservation and improve. According to the energy scene analyses of the following 20 years, to strengthen energy-conserving policy can make their rate of energy consumption increasing reduce by 15%~27%. Because the basic figure of energy consumption in industrial department is relatively heavy and our country is still in the industrialization course, the industrial department will be a rich family of the energy consumption. Making the strict efficiency policy can produce the obvious result. Energy-conserving policy may exert an enormous influence on improving the existing efficiency of production capacity. Various analysis and calculations indicate that the market feasible technology at present and the power-saving technology for economy rational may be up to 150 ~ 200 mtce every year.

So it is very necessary to emphasize that raising the efficiency of the energy terminal use technology can be considered as an important strategic objective of energy R&D of China in 21st century.

1.5. Relevance

Through the former discussions and study, it is clear that, to realize the national economic development goal of quadrupling the GDP from 2000 to 2020 and face the challenge of China's accession to WTO and global climate change, the Chinese government should address the following key problems on energy R&D:

To heighten the energy efficiency of end use technology should be considered as an important strategic goal of China's energy R&D in the 21st century, which aims to heighten the energy efficiency and realize the modernization of energy conservation through the research and exploitation of new technology.

To develop clean energy technologies with independent property rights, which are suitable for the Chinese contexts should be looked as a basic choice of energy S&T development strategy in China.

The coordination and combination of independent R&D and technology import should be tackled in the process of formulation and management of national policies on industry and industrial technology. National S&T programs should lay the foundation for the amalgamation of independent R&D and technology import in energy and create and accumulate the new model and new experience of domestic technology innovation continually.

2. Status quo of energy R&D in China

2.1. The situation of R&D in China

S&T has accomplished great headway since the reform and opening up of China. In the period of "Ninth Five-Year" Plan (1996-2000), the R&D outlays had risen continuously at a rate higher than the GDP growth rate. The adjustment of S&T institutional structure has advanced remarkably, which emphasized on the system conversion of research institutes majored in technology development to enterprises and classified reform of non-profit institutions, enterprises have begun to become the primary actor of R&D activities. System transformation of research institutes resulted in the decrease in the number of research personnel and organizations, but the general quality of human resources has improved. Besides enterprises, academies (including universities and R&D institutes) also played very important roles. The S&T activities of academies featured mainly in basic research. In recent years, their investment in basic research has increased considerably. Government has still been the main supporter of funds. At the same time, we should be conscious of the gap between the developed countries and China. In 2000 the investment in R&D accounted for 1.0% of GDP in China for the first time and then reached 1.1% in 2001 and 1.2% in 2002 respectively. However, the corresponding ratio of America has always kept above 2.5% over the recent decades and other developed countries' investments in R&D have been also much higher than China's, most of which were over 2%.

Table 2- 1. The ratio of R&D investments to GDP of China and some other countries (%)

Year / country	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
U.S.A	2.72	2.65	2.52	2.43	2.51	2.55	2.58	2.6	2.65	2.72	2.82	2.82
Japan	2.93	2.89	2.82	2.76	2.89	2.77	2.83	2.94	2.94	2.98	3.09	
UK	2.07	2.02	2.05	2.01	1.95	1.88	1.81	1.8	1.88	1.85	1.90	
Korea	1.92	2.03	2.22	2.44	2.5	2.6	2.69	2.55	2.47	2.65	2.96	
China	0.74	0.74	0.72	0.65	0.6	0.6	0.68	0.7	0.83	1.0	1.1	1.2

Data source: China Statistics Yearbook.

2.2. The status quo of energy R&D in China

Now, we account for the status of energy R&D budget and human resources mainly according to the statistics of 2000, moreover, we make a summary of energy

R&D academies and technology.

2.2.1. Expenditures

Energy technology is characterized by long innovation cycle and large investment, so compared with other industries, energy industry depends more on the choice of R&D technique and investment, especially state finance. In 2000 the investment in energy R&D classified by projects was 44.78 billion Yuan that accounted for 6.43% of total R&D expenditure, 696.69 billion Yuan. The outlay of energy projects accounted for 0.064% of GDP[1].

If we considered other expenses of R&D activities such as management expenses, service expenses, infrastructure expenditure and cooperation process expenses, China's energy R&D expenditure was 57.59 billion Yuan in 2000.

2.2.2. Human resources

In 2000, the FTE of R&D personnel in China are 740876 man-years. Energy industry accounted for 6.55% of all industries, 48540 man-years. Among the persons engaged in R&D of all industries, 509396 man-years were of scientists and engineers. 34828 man-years, which accounted for 6.84% of total industries, were input into energy industry. Thus it can be seen the education level in energy industry was higher than the average, however the input of energy R&D per employee was too low.

2.2.3. Institutions and infrastructures

The situation of institutions and infrastructures is shown in Appendix 1.

2.2.4. Technology

Coal preparation technology

Coal preparation technology is making progress gradually. In 1998 coal-washing capacity of coal preparation industry was 500Mt and original coal washing rate was up to 25.2%.

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[1] Ma Chi, Gao Changlin, Shi Han, "Research on China Energy R&D Investment", International Petroleum Economics, 2003

In 1999, popularization rate of coal briquettes in key cities was up to 80%; yield of civil coal briquettes in countries was 59.5Mt; capacity of industrial fuel briquettes was 8Wt; capacity of industrial gasification briquettes for fertilizer was 20Wt.

China's coal water slurry technology has entered commercialized-developing phase. In 2000, capacity of slurry plants amounted to 1.7Mt. The Baiyanghe Power Plant (3×50MW) in Shandong Province has been on commercial demonstration coal water slurry running since 1999.

Coal fired power

Supercritical and ultra supercritical power unit (flue gas clean-up equipment, burner with low-NOx) is at the experimental stage. We have imported 8 supercritical generating sets of 2×600MWe, 4×500Mwe and 2×800MWe.

On China's independent cycle fluidized-bed combustion technology, 410t/h (100MW) high-temperature & high-pressure CFB boiler unit has been set up at Fenyi Power Plant in Jiangxi Province; 440t/h (135MW) ultra-high temperature & reheat CFBC boiler unit has been put into operation; domestic technology CFB boiler under 130t/h (25MW) has occupied a majority of inner market. 300MWe CFBC imported project of demonstration engineer has been launched.

China's pilot test power plant (60t/h) of pressurized fluidized-bed combustion-combined cycle (PEBC-CC) has been set up and put to test-run in 2000. In the period of "Ninth Five-Year" Plan, some researches on key techniques of IGCC, such as technical gasification, coal gas purification, gas turbine, waste-heat recovery system, have started up. State electric power corp. planed to import a 300-400Mwe IGCC demonstration power plant by inviting public bidding in Shandong Province during the "Tenth Five-Year" Plan.

Coal transformation

Atmospheric fixed-bed gasification process technique is popular in China. New-style (multi-muzzle contraposition) pilot test equipment of coal water slurry gasification burner (22 tce/day) has run successfully at Lunan Fertilizer Plant in 2000. Its technical index was advanced. Industrialized demonstration equipment project of 1000 tce/day has been installed under the 863 Program. In 2001, ash melt assemble fluidized-bed industrialized demonstration equipment of 100 tce/day is combined into synthetic ammonia production system. The above-mentioned two demonstration projects indicate that our modern coal gasification techniques with independent intellectual property rights began to enter into the domestic market. At the same time, R&D activities on dry pulverized coal pressurize gasification technique has been put up.

On indirect liquefaction technology, researches on synthetic diesel catalyst and advanced slurry-bed synthetic gasoline technique have been carried on. New-style iron catalyst developed independently impels coal-based synthetic oil technique to industrialization stage. On direct liquefaction, we have finished basic research on direct liquefaction, which laid the foundations of further technical magnifying, building industrialized demonstration factories and technology introducing.

Flue gas purification

China imports diversiform desulfurization and burner with low-NOx techniques, but these techniques are immature and unpopular. On the one hand, we have imported numerous hydro-flue gas desulfurization equipments. On the other hand, we are developing multiform desulfurization technique and burner, such as cycle fluidized-bed flue gas desulfurization, simplified flue gas desulfurization and new-style E-beam half-dry flue gas purification etc.

Underground coal gasification

New technique as "Long Passage with Large Cross Section and Two-stage" is widely put into practice. The running projects of underground coal gasification are as follows: Liuzhuang mine in Tangshan, Sunzhuang mine in Xinwen of Shandong Province, Caozhuang mine in Feicheng of Shandong Province and Xiyang mine in Shanxi Province, etc.

2.3. Petroleum and Natural Gas Technology

In China, many advanced technologies, such as three-dimension earthquake exploration technology, high precision earthquake digital processing technology, computer interactive earthquake explanation technology, and all sorts of underground imaging technology, have been widely used. Imaging technology with domestic equipments and application software has been applied to Oil well survey.

On artesian well, technology has evolved to drilling directional well, horizontal well and high-temperature& high-pressure special technical well.

At present, exploration and development of coal gasification and coal bed gas, as well as research on unconventional oil gas resource survey technology should be strengthened. It is advantageous for utilizing unconventional oil gas resource in latter phase of 21 century in China.

Apart from strengthening survey technology research, it is necessary to make researches on fundamental theory of oil gas survey and petroleum geology. Survey practice will be guided effectively only when there is something original in theory.

On prospecting, a complete set of early-stage prospecting technology have formed, including affusion, layered prospecting, adjust prospecting lay well net by stages. While at late stage, injecting polymer to drive oil industrialization technology is developed, either level or scale of it is in the highest flight all over the world and it is the principle technology of oil field prospecting in China.

Both quality and structure of oil refining product are underdeveloped, so there is plenty of room for improving technology and reducing cost.

2.4. New Energy and Renewable Energy Technology

2.4.1. Wind power

Unit capacity of domestic units is up to 600KW, while that of import units is up to 1.3 MW. In 2000 total installed capacity of China amounted to 344MW.

2.4.2. Solar power

China’s annual capacity of photovoltaic cell has reached 4.5MW and total installed capacity was up to 18MW at the end of 2000. Photothermal power is in research.

2.4.3. Biomass energy

We have begun to utilize biomass energy. 1 MW biomass gasification power system has been installed in China. Now, it has been scaled up to 30 MW.

In the period of “Ninth Five-Year” Plan, much research work on biomass liquefaction has begun, such as ethanol, biomass-cracking oil, and vegetable tallow.

2.4.4. Ocean energy

Seven tidal power stations are running in China. Lantern wave electric power equipment is generally used in these stations. 100KW Coast-osclating water columns wave power plant has been built in the period of “Ninth Five-Year” Plan.

2.4.5. Geothermal power

100 KW flash vaporization test power plant was founded in Guangdong Province. Most of the middle-high temperature geothermal powers are built in Tibet. Total installed capacity is 28 MW.

Heat supply by geothermal power is widely used in China and 120-degree heat pump has been worked out.

2.4.6. Fuel cell

In China, 1KW molten carbonate fuel cell group has been manufactured successfully. Research on solid oxide fuel cell has begun and 30KW proton exchange membrane fuel cell system has finished.

2.4.7. Hydro-power

Hydrogen production test unit by desulfurization of hydrogen sulfide has been set up in China. Technology of making hydrogen by microbe has made great advancements and research on hydrogen saving is being carried on.

2.4.8. Hydrate of natural gas

Early research on formation and distribution mechanism and resource survey of Hydrate of natural gas has begun in China.

2.5. Nuclear Energy Technology

2.5.1. PWR

China is able to make a whole set of PWR with a capacity of 300 MW by domestic technology and it has great capabilities to produce fuel module of 600MW and GW level nuclear power station.

2.5.2. High temperature gas-cooled reactor

China has built 10MW pebble-bed high temperature gas-cooled experimental reactor.

2.5.3. FBR (Fast breeder reactor)

In China, FBR-65MW is under construction experimental reactor.

3. Analysis on China’s Energy R&D Inputs

3.1. Status quo, structure and characteristics of China’s energy R&D inputs

3.1.1. Overall national R&D inputs

The research on China’s energy R&D inputs and corresponding policies is nearly a complete missing. The statistics concerning energy technology and information on R&D data in relation to conventional fossil fuel production and conversion, renewable energy development, and energy efficiency technologies are both fragmented and scarce. This situation has caused great difficulty for relevant governmental departments to make energy-related decisions, especially with regard to project choice and R&D fund allocation. National census on R&D resources in 2000 provides us with reliable data foundation for comprehending China’s energy R&D input from time section.

According to the comprehensive data compilation of national R&D resource check in 2000, the statistical data of energy R&D can be got by counting energy industry data, which is according to "groups of national economy industry the project served" in "national research and experiment development(R&D) project (subject) situation".

The statistics include all R&D projects (subjects) of national independent science & research institutions, S&T information and literature organizations, fulltime ordinary colleges, also include R&D projects (subjects) beyond RMB 100,000 yuan (including 100,000) of large-and-middle-scale industry enterprises, building enterprises, transportation warehouse enterprises, post and telecommunication enterprises, R&D projects (subjects) beyond RMB 50,000 yuan (including 50,000) of small-sized industry enterprises above some scale, R&D projects(subjects) beyond RMB 10,000 yuan (including 10,000) of other units.

The national R&D expended RMB 89,500,000,000 yuan, including direct expenditure of R&D projects (subjects) activities, also including indirect expenditure such as management charges and service charges for R&D activities, R&D related basic facility investments, external collaboration fees, etc. As Table 3-1 was the direct expenditures, amounting to RMB 69,600,000,000 yuan. In 2000, national R&D expenditure accounted for one percent of GDP (gross domestic product), which was RMB 8,956,600,000,000 yuan. Estimated reasonably, energy R&D expenditure accounted for 0.0643×1%=0.064% percent of GDP (See Table 3-1).

3.1.2. The government funds

According to R&D direct expenditure by projects statistics, national energy R&D expenditure in 2000 was RMB 4,478,000,000 yuan, in which government capital was RMB 477,000,000 yuan and accounted for 10.65% (referring to table 3-1). So government energy R&D expenditure in 2000 accounted for 0.064% × 10.65%=0.0068% of GDP.

Besides government input, there was enterprises financing including bank credits.

Table3-1. National energy R&D and industry R&D situations in 2000 (Counted according to the projects)

	Personnel's full-time equivalent (man-year)	Number of scientists & engineers	R&D expenditures (RMB million Yuan)	Government outlays (RMB million Yuan)
Coal mining and preparation	5093	3612	639.174	31.614
Petroleum & natural gas exploitation	12553	9566	1052.131	154.880
Petroleum processing and coking	7104	5059	797.479	30.178
Boiler and Prime	10628	6767	649.982	128.503
Electrical	4501	3193	297.626	39.154
Production and Supply of the Electric power,	8303	6363	1002.216	85.579
Production and Supply of Coal	358	269	39.102	6.913
Subtotal of the energy industry	48540	34828	4477.710	476.821
All industries	740876	509396	69669.389	24664.032

Energy R&D proportion (%)	6.55	6.84	6.43	1.93

Data source: The Science and Technology Statistics Information Center of Central China University of Science and Technology

3.1.3. The feature of technological development of energy industry

We first make the comparison between energy industrial technological development inputs, other technological activities inputs and relevant inputs of all industries. The so-called other technological activities include technological transformation, foreign technology import, acquisition of domestic technology, etc. This contributes to understanding energy industry's characteristics of present technological development and reliance situation on foreign technology. From 1990s, there were the statistics data for the study on this problem. We list the data of 2001, 2000 and 1993 here (see Table 3-2), as the basic data of investigating this question. According to the table, we know that large-and-middle-scale enterprise energy industrial technological development funds proportion to all industries is about 10% at present (11.6% in 2000, 9.7% in 2001), which have increased greatly compared with 1993 (6.5%). At present, the proportion that other technological activities funds expenditure of the energy industrial enterprises account for all industries is 17%, compared with 1993 increased by a large margin too. Furthermore, research and analyze this group of data as follows:

Table3-2. Intramural expenditure on technological development and expenditure on other technological activities of large-and-middle-scale energy industrial enterprises (Unit: RMB100,000,000 Yuan)

			Total of all industries	Coal mining and preparation	Petroleum and natural gas Exploitation	Petroleum Processing and Coking products	Electric power, steam, hot water production and supply	Coal gas production and Supply	Subtotal of energy industries	Proportion of energy industries (%)
Expenditure on other technological activities	Subtotal	2001	1606	23	4.21	120	129	1.99	279	17.4
		2000	1422	19.2	11.4	104	106	2.78	244	17.2
		1993	791	4.52	24.6	26.2	14.5	2.18	72.2	9.1
	Technological renovation	2001	1264	18.9	2.71	113	120	1.94	223	17.7
		2000	1132	14.3	10	96.3	101	2.75	224	19.9
		1993	621	4.2	22.4	24.8	14	2.14	67.7	10.9
	Technology import	2001	285	3.69	1.43	6.74	5.24	0.04	17.1	6
		2000	245	4.52	1.01	7.71	3.47	0.02	16.7	6.8
		1993	159	0.32	2.15	1.24	0.49	0.04	4.23	2.7
	Technology assimilation	2001	19.6	0.18	0.02	0.14	0.09	0.001	0.44	2.2
		2000	18.1	0.14	0.16	0.43	0.12	0.002	0.86	4.7
		1993	6.23		0.05	0.09	0.02	0	0.16	2.6
	Purchase of domestic technology	2001	36.3	0.65	0.05	0.49	3.19		4.38	8.7
		2000	26.4	0.21	0.26	0.51	1.32	0.01	2.31	8.7
		1993	4.72	0	0.01	0.07	0.02	0	0.11	2.3
Intramural expenditure on Technological development		2001	977	17.8	29	15.3	31.8	0.87	94.9	9.7
		2000	823	15.5	26	24.9	27.8	0.93	95.3	11.6
		1993	248	1.15	7.07	5	2.67	0.36	16.2	6.5

Data source: China's science and technology statistics yearbook

Firstly, we analyze the ratio of technological development funds expenditure to other technological activities funds expenditure. The rate of energy industry is obviously low. This indicates that compared with all industries of large-and-middle-scale enterprise, technological progress of energy industry rely more on technological transformation, technology import and buying domestic technology outside of enterprises.

Table3-3. The ratio of the intramural expenditure on technological development to the expenditure on other technological activities of large-and-middle-scale energy industrial enterprises (%)

Year	2001	2000	1993
All industries total	0.61	0.58	0.31
Coal Mining and Dressing	0.76	0.81	0.26
Petroleum and natural gas exploitation	6.91	2.27	0.29
Petroleum Processing and Coking products	0.13	0.24	0.19
Electric power, Steam, Hot water Production and Supply	0.25	0.26	0.18
Coal gas Production and Supply	0.44	0.33	0.17
Subtotal of Energy industries	0.34	0.39	0.23

Data source: China's Science and Technology Statistics Yearbook

Among them, energy mining industry, namely primary energy production, is obviously higher than the whole situations of energy industry to the reliance of technological development inside enterprises, especially the exploitation of petroleum and natural gas have improved the technological development inside enterprises more in recent years.

The technological development situations of secondary energy production are contrary to above-mentioned primary energy production. Typically, the petroleum processing and electric power, compared with energy industry wholly, rely more on other technological activities beyond inner technological development.

Therefore, in the technological progress of energy industry, technological developments inside enterprises of primary energy productions are more active; meanwhile secondary energy productions depend more on exterior technology whose main forms are technological transformation and technology import.

Table3-4. The ratio of the expenditure sum of technology import and technology assimilation to the expenditure sum of technology import, technology assimilation, purchase of domestic technology and technological development of

large-and-middle-scale energy industrial enterprises (%)

Year	2001	2000	1993
All industries total	23.1	23.7	39.5
Coal Mining and Dressing	17.3	22.8	21.5
Petroleum and natural gas exploitation	4.7	4.3	23.7
Petroleum Processing and Coking products	30.3	24.2	20.8
Electric power, Steam, Hot water Production and Supply	13.2	11.0	15.8
Coal gas Production and Supply	4.8	2.5	9.4
Subtotal of Energy industries	14.9	15.3	21.1

Data source: China's science and technology statistics yearbook

We use the statistical data and the ratio of sum of technology import, assimilating expenses to sum of technology import, assimilating, buying domestic technology, technological development expense to measure the degree that the technological progress of industrial enterprises relies on foreign technology. It can be found from table 3-4 that:

Compared with all industries of the large-and-middle-scale enterprises, energy industry’s degree of dependence on foreign technology is obviously low. Moreover its degree of dependence dropped gradually since the initial stage of the 1990s so far.

Among them, compared with energy industry's average level, petroleum processing and coking, coal mining and selecting depend more on foreign technology. The data in recent years indicate, in energy industry, exploiting petroleum and natural gas, production and supply of coal gas depend less on foreign technology. The dependent degree of production and supply technology of electric power, steam, hot water on foreign technology is lower than energy industry average level.

Through analyzing above-mentioned technology statistics, we can get the following conclusion:

Compared with initial stage of the 1990s, in the large-and-middle-scale industrial enterprises at present, the proportion of energy industry’s technological development funds and other technological activities funds (technological transformation, technology import, buying domestic technology) to all industries has increased by a large margin, up to 10% and 17% separately. Namely the technological activities funds expenditure of the energy industrial enterprises has increased greatly in all industries.

Compared with all industries, the rate of energy industry's technological development funds to other technological activities funds is obviously on the low side. This indicates that the technological progress of energy industry relies more on enterprises' external technology, achieving the technology upgrading of enterprises through technological transformation, technology import, buying domestic technology outside of enterprises. However, primary energy production, especially exploiting petroleum and natural gas is contrary to this situation.

We use the ratio of sum of technology import, assimilating expenses to sum of technology import, assimilating, buying domestic technology, technological development expense to measure the degree that the technological progress of industrial enterprises relies on foreign technology. The result of calculation indicates, compared with initial stage of the 1990s, the dependent degree of energy industry as well as all industries on foreign technology has declined obviously in the large-and-middle-scale industrial enterprises at present.

Compared with all industries, the dependent degree of energy industry on foreign technology is low. But in energy industry, there is a greater dependence on foreign technology in petroleum processing than in exploiting petroleum and natural gas, production and supply of coal gas.

3.2. Input to energy R&D of the national programs of S&T

3.2.1. Management of national programs of S&T funds

The national programs of S&T are the important form for government to support research and development activities. During the tenth Five-Year plan period, the national programs of S&T rounds the thread of economic development firmly, carrying on strategic deployment in two aspects which are promoting industry's technology upgrading and improving lasting innovation ability of S&T. During the tenth Five-Year plan period, national programs of S&T is deployed on the basis of "3+2" system, which consists of three subject programs - the National High-tech Research and Development Program (863 Program), National Program of key S&T Projects, the National Program for Key Basic Research Projects (973 Program), and two environmental construction programs - R&D conditions construction and commercialization environmental construction. The financial funds of the national programs of S&T mainly come from the S&T funds managed by department of MOST (See Table 3-5).

Table3- 5. Financial fund approaches of the national programs of S&T

Funds for S&T Development			973 Program	863 Program	National Program for Key S&T Projects	The Torch Program	The Spark Program	National S&T Results Dissemination Program	The S&T Program for Social Development	National Natural Science Foundation
Scientific operation expenses	Operation expense of natural science	Technological development studying								
		Basic research funds								
		Social public goods and agricultural research funds								
		Technological development funds for industries								
		Funds of management organization of scientific research								
		Natural science foundation								●

		Special awards for S&T								
	Operation expenses of Chinese Association for S&T									
	Special funds of high-tech research			●						
	Operation expense of social science									
Special funds of national key basic research projects			●							
The Three Expenses for S&T*					●	●	●	●	●	
Funds for S&T foreign affairs										
Special R&D funds for S&T institutions										
Funds for publishing academic works										
Capital construction funds										
Funds of Chinese Academy of Sciences										

Note: * The Three Expenses for S&T include fees for trial production of new products, pilot test and key scientific research project allowances.

3.2.2. Energy R&D input of national programs of S&T

In the statistics of national programs of S&T, according to statistics classification in the world, social economic goals projects served are divide into the following 11 kinds: development of the agriculture, forestry and fishery, prompting the advancement of industry, production and rational utilization of energy, development of the infrastructure, environment monitor and protection, hygiene, social development and community service, exploration and use of the earth and atmosphere, knowledge development in an all-round way, civil space and world, etc.

Data listed in table 3-6 are preliminary investigation and statistics of energy R&D funds in 2000 that was in the three major national programs of S&T during the tenth Five-Year Program period. In 2000, the project funds for production and rational utilization of energy in 863 Program, 973 Program and National Program of Key S&T Projects were RMB600 million yuan, accounting for 10.44% of the total funds of three major programs. Government funds accounted for a proportion of 46.0% among projects of three major programs. If we calculate according to this proportion, government's funds were probably 6.0*46.0% =RMB 276 million yuan among the projects funds for production and rational utilization of energy. It has already been mentioned that government funds were RMB 477 million yuan in national energy R&D funds in 2000. So we can estimate that the proportion accounted for three major programs is close to 60% in government energy R&D funds input. So, we can say that the national programs of S&T are the main approaches of government investments in energy R&D.

Table3-6. The funds of national programs of S&T in energy fieldby the socio-economic objective(2000)

	Funds allocated in 2000 (RMB 10000 yuan)			
	Total	973 Program	863 Program	National Programs of Key S&T Projects
Total	570818	68760	148773	353285
Production and adequate use of energy	59576	11320	12085	36171
Proportion of energy projects (%)	10.44	16.46	8.12	10.24
Government funds	262814	64742	63238	134833
Proportion of government funds (%)	46.0	94.2	42.5	38.2

Note: * the socio-economic objectives include 11 kinds such as: development of the agriculture, forestry and fishery, promotion of industrial development, production and adequate use of energy, development of infrastructure, monitoring and protection of environment, development of health service, social development and social service, exploration and utilization of the earth and its atmosphere, general advancement of knowledge, civil space and national defense.

Because there is no statistical data about the national programs of S&T in the China's Science and Technology Statistics Yearbook in 2001, we obtained the following data by first-hand data collection and interview.

The National Program for Key Basic Research Projects (973 Program)

Since 1998 to 2002, the 973 Program had already started 132 projects successively, in which there were 15 items in the energy field. Energy and energy closely related projects with planned allocation of funds included 10 items in 2001. The sanction amount of national special funds in that year is RMB 68,060,000 yuan. (There may be certain overestimation while calculating. Because some projects such as "Catalysis foundation for optimized utilization of natural gas and coal-bed methane" and "The petroleum refining and green chemistry of the synthesis of basic organic chemicals "not merely serve the energy.)

The National High-tech Research and Development Program (863 Program)

The 863 Program has been supporting 6 themes, one of which is energy. Meanwhile there are subjects closely related to energy too in the fields of resource, environment and new materials. Still there are important projects under 863 Program and the energy project is one of them.

According to the preliminary statistics, allocated funds in energy field reached RMB 56,980,000 yuan, allocated funds in energy important projects reached RMB 30,450,000 yuan, allocated funds in energy related projects in resource, and environment field reached 11, 750,000, the sum of three items amounted to RMB 99,180,000 yuan, accounting for 13.6% in all allocated funds in 2000.

National Program of Key S&T Projects

In the tenth Five-Year Plan, four major projects, clean energy action, renewable energy industrialization, energy-conservation and exploitation of oil and gas resources, got allocation of RMB 155,600, 000 yuan. The execution duration of these projects and subjects is not the same. Some are 3 or 4 years, while others are 2 years. But their allocation has been finished between 2001 and 2003. The average annual input of key S&T projects in 3 years, which was regarded as the estimation of national government allocation in 2001, reached RMB 51,870,000 yuan, accounting for 6.5%. For the convenience of comparison with the year of 2000, the data on annual expenditure of S&T programs during the 10th five-year plan were chosen.

Others

Among the subsidy projects of National Natural Science Foundation in 2001, there were 75 projects on engineering thermophysics and utilization of energy, which amounted to 14,890,000 yuan, namely 10. 98% of the subject of engineering and material science and 1.87% of the whole committee; There were 4 key projects, which amounted to 5 million, namely 11.66% of the subject and 2.77% of the whole committee. In the subject of management science, there were 2 projects about energy management, which amounted to 250,000 yuan, namely 1.01% of the subject and 0.031% of the whole committee. In the subject of management science, there are few research projects about energy in recent years.

In addition, the Chinese Academy of Sciences invests about RMB 58,090,000 yuan to energy R&D in its affiliated main research institutions of energy such as coal chemistry institution of Shanxi, energy institution of Guangzhou, engineering thermophysics institution, chemistry and physics institution of Dalian.

The aforementioned totals about RMB 300 million yuan. This and the published statistics of 2000(seen from Table 3-6) are almost equal.

The listed data of table 3-7 is about the funds of national programs of S&T during the ninth Five-Year Plan period from 1996 to 2000. Rough analysis can find out that implemented fund in that year is from RMB1, 210 million yuan in 1996 to RMB 5,710 million yuan in 2000, presenting the progressively increasing trend year by year, and the average annual growth rate is up to 47.27%.

Table3-7. Funds situation of projects of national programs of S&T during the ninth Five-Year Plan period (climbing the 863, Key S&T Projects) Unit: RMB 10,000 yuan

Year	Arranged funds	Government funds (%)	Arranged fund of energy	Fund proportion of energy projects (%)
1996	121355	55488 (45.7)	12672	10.44
1997	220898	109621 (49.6)	19238	**8.70**
1998	288028	130433 (45.3)	16819	5.84
1999	406175	190451 (46.9)	42857	10.55

2000	570818	262814 (46.0)	59576	10.44

Note: *Production, storage and distribution of the energy, this is a classification of national economic activities according to the socio-economic objectives.

*Source of data: China's Science and Technology Statistics Yearbooks (1996-2002)

In all programs of S&T, the range of government fund proportion is from 45.3% to 49.6% that varies little. The government input proportion of 973 Program (Key basic research development program) is the biggest, much greater than Key S&T Program. The latter is about 40% and the former is about 95% in most years. In 863 Program, government fund proportion is different to some extent, from 82.3% of 1996 to 42.5% of 2000, presenting the steady downward trend year by year. It indicates that the support outside the government to the high-new technical development is strengthened year by year.

During the ninth Five-Year Plan period, the funds of energy projects have increased by a relatively large margin in the national programs of S&T, rising from RMB127 million yuan in 1996 to RMB 600 million yuan in 2000(referring to table 3-7), and the average annual growth rate is 47.25%, which keeps the simultaneous growth with the project funds of national programs of S&T.

The proportion of energy R&D project funds in 863 Program is still higher, being 14.3% on average during the eighth Five-Year Plan period and 15.9% on average during the ninth Five-Year Plan period (see Table 3-8).

Table3-8. Funds input to projects on energy technology under 863 Program* Unit: RMB10,000yuan

	Year	Allocated funds of program	Allocated funds on energy technology	Proportion of allocated funds on energy technology (%)
The Eighth Five-Year Plan period	1991	18611	2624	14.10
	1992	23155	3038	13.12
	1993	29120	3874	13.30
	1994	31764	4223	13.29
	1995	26870	4800	17.86
The ninth Five-Year Plan Period	1996	45000	6448	14.33
	1997	50538	12601	24.99
	1998	63875	16819	26.33
	1999	100421	16944	16.87
	2000	148773	12085	8.12

Note:* Production, storage and distribution of the energy, this is a classification of national economic activities according to the socio-economic objectives.

3.3. The international comparison of the governmental energy R&D input

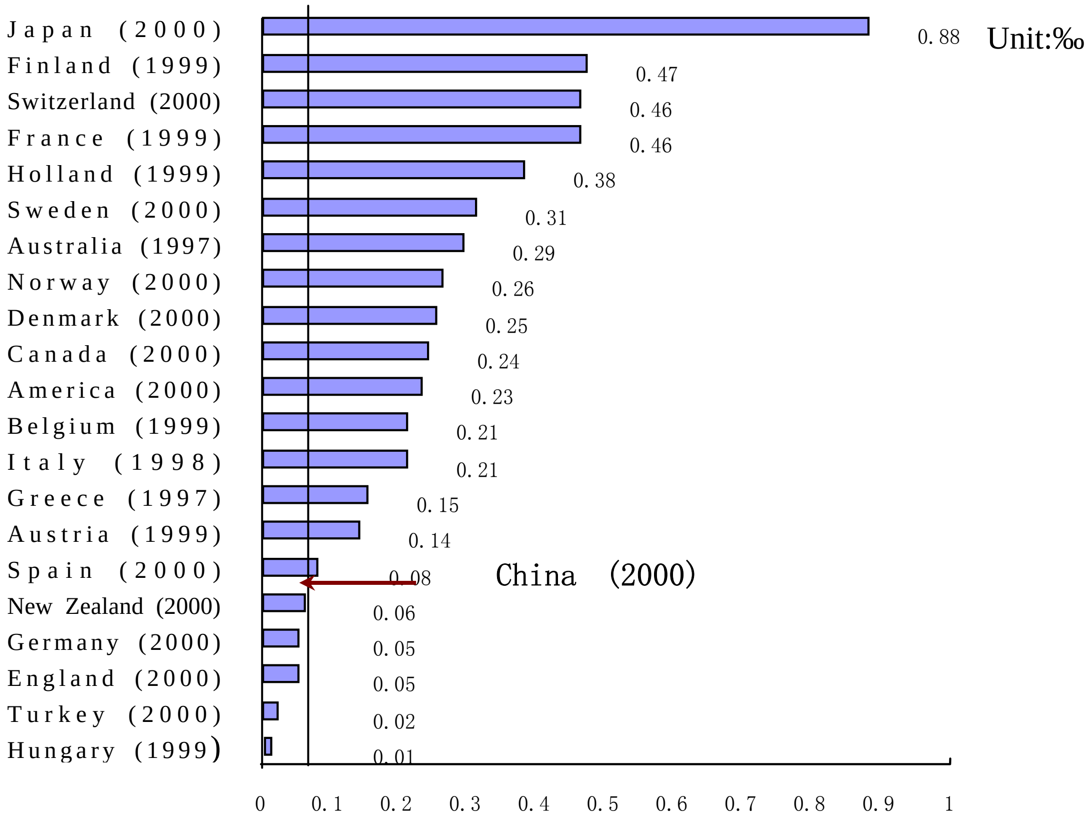
3.3.1. The intension of the governmental energy R&D devotion

According to the relative data, we collected the data of national government energy R&D budget of some IEA countries, which are shown in the table 3-1.

According to the calculation with the investigation survey data from Comprehensive Compiles R&D Resource of China in 2000, energy R&D funds took 0.068% of the whole GDP of China.

So, the ratio of the government energy R&D budget to GDP in 2000 in China was between New Zealand and Spain, and far below most developed countries. Here the ratios of the government energy R&D budget of some countries to GDP in some developed countries were bigger than China's, such as Japan (0.88‰), Finland (0.47‰), France (0.46‰), Switzerland (0.46‰), Holland (0.38‰), Sweden (0.31‰) and Australia (0.29 ‰). Moreover, there were few developed countries whose ratio was lower than China, such as Germany (0.05 ‰) and England (0.05 ‰).

Figure 3-1. The ratio of government energy R&D budget to GDP in some IEAs countries



Note: The number after the national name means the year of the statistics.

Data resource: Energy Policies of IEA Countries, 2001 Review

Above data are primarily have the developed countries. As one of the main developing countries, India related data has some value to consult.

From 1996 to 1997, the budget of the Indian R&D is 83.4 billion Rupee, which equaled to 2.34 billion US$ calculated with market exchange rate (MER) or 11.5 billion international dollar calculated with purchasing power parity (PPP). Comparing with the major industrialized countries, the budget of Indian R&D is quite little.

Governmental devotion is the main way that the budget of Indian R&D comes from, for example from 1996 to 1997 accounting with 109 rupees in 1993, R&D adds up to 64.8, among them central government is 45.2, national government is 5.6, privately owned section is 14.0, then respectively take 69.8%, 8.6% and 21.6%. But the budget of Chinese R&D which government devotes inside of all only takes 35%. Compared with India, the proportion of the budget of Chinese R&D which government devotes is much lower.

Table3-9. Comparison of Indian & the major industrialized national R&D budget (1996 data)

Country	National R&D budget (billion US$)	Percent of GDP (%)	Per capita (US$)
India (MER)	2.34	0.59	2.5
India (PPP$)	11.5	0.59	12.1
United States	195.9	2.57	739
Japan	85.1	2.83	676
Germany	39.7	2.3	485
France	27.7	2.32	475
United Kingdom	22.3	1.95	380
Italy	12	1.02	209
Canada	10.8	1.6	365

Classifying the social economic goals as UNESCO, from 1996 to 1997,the budget of Indian resource R&D is 6.19×10^9 Rupee, which is equaled to 0.85×10^9 PPP$ (international dollar calculated by the purchasing power parity), and took 7.6% among the budget of national R&D. Compared nearly, the budget of Chinese R&D is RMB 89.5 billion, among which the budget of resource R&D is 5.759 billion RMB which is equaled to 0.69 billion dollars or equaled to US$3.22 billion PPP. Although these two data don't come from the same year, we can see from the quality level that the absolute quality of the budget of Chinese R&D of energy sources is higher than India, but the proportion of the budget of national R&D is lower than India.

3.3.2. The distributing of the outlay of the R&D of the national energy sources in the domain of technology.

According to the composing of the outlay of governmental energy sources in table 3-9, the statistics of the IEA states in 1999 showed that the first is nuclear energy, and nearly 50% of the outlay of the R&D of the energy sources was used in it. It includes the study of the fission reactor (breeder reactor, nuclear fuel cycle, etc.) and nuclear fusion. There are some states whose outlay of the R&D of the nuclear energy is above one third of the outlay of the national energy R&D, such as France (91.43%), Belgium (81.66%), Japan (70.71%) and Spain (38.69%). And the devotion of the R&D in the domain of the nuclear energy of some other countries was very high too, for example England (30.22%), Canada (28.48%) and Switzerland (24.06%).

And the percent of the United States is 12.05%. But German, New Zealand and Portugal seldom invest in the research of the nuclear energy.

The second is energy conservation in the composing of the outlay of governmental energy sources. The whole devotion of these nations took more than 16 percent in 1999. There are a lot of countries that they invest more in this domain, such as Finland (44.55%), Holland (37.13%), Sweden (31.66%), America (23.77%),Germany (14.23%),and England (2.43%).

Table3-10. the distribution of government energy R&D expenditure by energy technologies

The distribution of the energy / Nation (year)	Total	Conservation	Oil & Gas	Coal	Renewable energy	Nuclear power	Power	Energy system and other technology
Austria (1999)	100	28.76	0.53	1.92	34.93	11.13	11.42	11.31
Belgium (1999)	100	8.13	0.49	1.15	2.00	81.66	5.42	1.14
Canada (2000)	100	24.79	21.16	2.49	7.29	28.48	3.67	12.13
Denmark (2000)	100	29.32	4.16	0.06	36.93	10.12	7.92	11.49
Finland (1999)	100	44.55	3.96	3.87	9.78	13.77	19.96	4.11
France (1999)	100	1.88	4.67		2.03	91.43	—	—
Germany (2000)	100	14.23	—	17.39	56.28	—	5.13	6.96
Hungary (1999)*	100	—	—	—	—	96.54	3.46	—
Japan (2000)	100	15.73	0.71	2.21	4.14	70.71	4.46	2.03
Netherlands (1999)	100	37.13	5.43	1.42	29.62	9.80	8.02	8.57
New Zealand (2000)	100	15.49	16.81	10.12	31.2	—	17.23	9.15
Norway (2000)	100	3.51	54.05	—	11.68	16.49	5.30	8.97
Portugal (2000)	100	13.81	4.46	17.34	51.68	—	1.02	11.7
Spain (2000)	100	7.32	0.18	7.18	28.9	38.69	3.09	14.63
Sweden (1999)	100	31.66	—	0.07	18.78	7.64	21.97	19.88
Switzerland (2000)	100	17.65	6.42	—	31.55	24.06	13.37	6.95
Turkey (2000)	100	5.39	3.62	34.86	30.91	4.73	17.13	3.35
U.K. (2000)	100	2.43	6.47	3.45	11.81	30.22	4.22	41.41
U.S. (2000)	100	23.77	3.82	5.33	9.30	12.05	5.46	40.27
Total (1999)**	100	16.48	2.94	3.89	8.10	48.79	4.52	15.28

Note: * the data of Hungary is not all.

** The total is the data in 1999.

The third is the energy system and the other technology, the whole devotion of these nations took more than 15.28%. The devotion of England (41.41%) and the U.S. (40.27%) are much higher in this domain, and Sweden (19.88%) is rather high too.

The proportion of the devotion of the above stations' renewable energy is 8.10%, which are higher than that of fossil energy that is 6.83%. The nations with high devotion to the renewable energy are Germany (56.28%), Portugal (51.68%), Denmark (36.93%), Austria (34.93%), Switzerland (31.55%), New Zealand (31.20) and Turkey (30.91%), etc. Seen from above, there are a lot of IEA nations are developing renewable energy.

Turkey (34.86%), Germany (17.39%) and Portugal (17.34%) invested a lot in the R&D of coal. Norway (54.05%), Canada (21.16%) and New Zealand (16.81%) invested more in gas.

The absolute quantity of the outlay of the R&D of governmental energy sources of Japan and the United States is far higher than other nations. The budget of Japan, America, France, Canada, Holland and Switzerland are all above 0.1 billion dollar.

The outlay of the R&D of Chinese governmental energy sources is 0.609 billion yuan which equal to 0.073 billion dollar. It is lower than all developed countries, which only took 1.8% of Japan.

The difference is very big between not only in the quantity of the outlay of each of the national governmental energy R&D, but also in the advanced domain they invested. In the table 3-11, it lists the budget of these national governmental energy R&D in 1999 and the priority of the distribution in the different researching domain of the energy technology, such as saving energy, oil, gas, coal, renewable energy, nuclear, electric power and other energy system and technique.

According to the accomplished form of government energy R&D funds which are ordered by share of technological field, we can find the trends that energy R&D of most countries is put into and assigned. Firstly, there are nine nations among the nineteen stations with complete data of 1999 which put the renewable energy on the first or second while the other ten nations put the saving energy on the same position. And especially on renewable energy, there are six nations which put it on the first of the outlay of national R&D. Secondly, there are nine nations which put the input of nuclear research on the first or second. Although the construction of nuclear power station has been in the data of stagnancy all over the world, the R&D of nuclear power have widely been done with the high input. There are five nations, which put it on the first in the order of number of the outlay, such as Japan, France, Canada, etc. Of course, input in the R&D of nuclear power will decrease later. Thirdly, America and England are worth to be remarked, research on the new energy system and technology is the mainly invest of their energy R&D. Fourthly, only a few nations put the fossil energy R&D on the first, for example Norwegian oil and gas and Turkish coal, decided by its national resources characteristics.

The distribution of energy R&D funds of China was like the below in the technical fields: oil /gas (gas exploitation and oil machining etc.) with 41.3%, coal (coal choosing and mining, coal gas and boiler manufacture) with 29.7%,electricity/heat (electric power, steam and hot water producing and serving and electrical machine manufacture) with 29%. Due to the classification of the statistics, the data of energy saving, renewable energy and nuclear energy were not separated in Comprehensive Survey of R&D Resources of China in 2000. So the distribution mentioned above was just a cursory data.

Table3- 11. The outlay and order of governmental energy R&D and the share order of outlay composing in technology field (1999).

Country	Governmental energy R&D		the order from big to small of the composing share of the energy R&D outlay						
	Outlay	Ranking	Conservation	Oil & gas	Coal	Renewable energy	Nuclear power	Power	Energy system and other technology
Japan	3955.74	1	2	7	4	5	1	3	6
US	2341.97	2	2	7	6	3	4	5	1
France	573.63	3	4	2	-	3	1	-	-
Canada	172.97	4	2	3	6	5	1	7	4
Netherlands	133.19	5	1	6	7	2	3	5	4
Switzerland	107.76	6	3	6	-	1	2	4	5
Germany	106.82	7	2	-	3	1	-	4	5
U.K.	66.01	8	6	4	7	3	2	5	1
Sweden	64.92	9	1	-	6	4	5	2	3
Finland	52.79	10	1	6	7	4	3	2	5
Norway	49.04	11	6	1	-	3	2	5	4
Spain	47.43	12	5	7	4	2	1	6	3
Belgium	46.63	13	2	7	5	4	1	3	6
Denmark	39.74	14	2	6	7	1	4	5	3
Austria	24.57	15	2	7	6	1	5	3	4
Turkey	3.38	16	4	6	1	2	5	3	7

New Zealand	2.83	17	4	3	5	1	-	2	6
Portugal	1.88	18	4	5	2	1	-	6	3
Hungary	0.29	19	2	7	4	5	1	2	-
Total	7791.59		2	7	6	4	1	5	3

3.4. Main policy problems on the investment of energy R&D

3.4.1. Chinese government invests little in energy R&D

In 2000, government invested only 0.0068% of the whole energy GDP of China, which is much lower than most developed countries, like Japan with a percentage of 0.088%. The absolute quantity of China was even lower, making only 1.8% of that of Japan. And government funds rate was 35.40% in R&D funds inside China, while the counterpart in energy R&D was only 10.65%, much lower than the average level. Considering both international experience and national situation, we need to consider more about investments of energy R&D that usually has a long cycle and requests large amount of investment.

3.4.2. The investment of National S &T Program into energy R&D was rather stable

The Chinese government has been continuously funded about 10%, larger than 6.43%, percentage of energy R&D of national R&D funds. Besides, NSTP make up to nearly 60% of energy R&D of national R&D funds. That is why we study NSTP here. In the other sense, although NSTP invests so much, other ministries and local government invests less than enough, which would also lead to a lower percentage of government investment.

IEA countries, 1999 (see Table 3-10) shows that energy saving came to the second place in government energy R&D funds, which is more than 16%. In China this kind of data were not collected, but according to the data from 2000 Comprehensive Collection of R&D Sources in China, there were only 2.0% invested in energy saving in industries that held 53.38% of the whole R&D funds in China. This may be not accurate enough, but surely a good way to see how little we have invested in energy saving. Therefore china should enhance the investigation and statistics of energy conservation data. It is urgent to formulate favorable policies on energy R&D to increase the input into energy conservation.

3.5. China’s energy R&D inputs in 2020

Facing the energy demand to build a well-off society in an all-round way and realizing the goal of energy doubling and GDP quadrupling from 2000 to 2020 must depend on the progress of the science & technology, raise the service efficiency of the energy, increase the energy supply and improve the energy resource structure. What level should the R&D input of energy in our country reach in 2020? We should put forward to the objective prediction of the energy R&D input of our country, according to the situation of domestic and abroad R&D input of energy.

3.5.1. National R&D expenditure of 2020

According to the general requirement to implement the strategy about revitalizing the nation through science and education and the overall principle on the development of science & technology and education being superior to economic development, we can design the medium and long-term scientific and technological development goal of our country. Meanwhile, we should realize that our country would be at primary stage of socialism in quite long period. And we must fully consider the possibility of realizing the goal of development in science and technology from such fundamental realities of the country. According to above-mentioned principles, we can predict that from now to 2020, our country should increase R&D input by a wide scope and encourage the whole society to plunge into scientific and technical innovation. On the basis of realizing the goal of the 15th program for the development of science and technology, the whole society R&D funds will reach RMB 370 billion yuan in 2010 and the R&D/GDP is up to 2% in 2015. From 2015 to 2020, the index of the R&D/GDP will be up to and keep steadily between 2.5% and 3%. If the R&D/GDP is up to 2.8% in 2020, the R&D input will be RMB 1,000 billion probably. As a result our country will build scientific and technological ability that can support the well-off society in an all-round way building and reach the scientific and technological competitiveness level of the medium-sized developed country in the world.

3.5.2. The proportion of energy R&D expenditures to the national total R&D expenditures

Production and rational utilization of energy is one of the important social economic goals for the R&D funds service in many countries and is of different importance in different historical stage. According to the data in OECD scientific and technical basic data database 2002, the proportion of the production and rational utilization funds of energy among the whole country R&D funds in Australia was 4.13% in 1984. It was 5.32% and 5.18% respectively in 1994 and 1996. It dropped to 3.92% and 3.53% respectively in 1998 and 2000. The proportion in Czech is average 3.66% from 1998 to 2001. The proportion of Iceland has been lasting downward trend since the eighties, and dropped from 12.9% in 1983 to 2.21% in 1999. This proportion was about 6% in middle period of 1990s in Korea. The proportion in Norway was

5.72% and 6.60% respectively in 1997 and 1999. The proportion in Spain is 6.53%, 5.91% and 4.40% respectively in 1995, 1997 and 1999. In our country the production and use funds of energy in all R&D projects was about 4,480 million yuan in 2000. And the proportion was 6.43%, which was higher than Australia's, Czech's and Iceland's and was similar to Korea's, Norway's and Spanish's in later stage the 1990s. For being lack of the data of other countries, we can't understand roundly the state of the energy R&D funds all over the world. But we can watch from limited data that the proportion of energy R&D funds accounted for R&D funds is not too low in our country. Taking the deficiency of energy supply in our country and the demand of clean with high capacity and efficiency source for building the well-off society in an all-round way into consideration, in quite long period in the future, the proportion of the funds for energy production and rational utilization accounted for the R&D funds in the whole country should keep present level and be proper to raise. According to the above judgment, we can confirm 7% as the objective proportion in 2010 and 8% in 2020.

3.5.3. The energy R&D input from the government

The proportion of the funds for energy production and rational utilization in government R&D budget reflects the preferential degree of energy in government R&D subsidy policy. According to the data in OECD scientific and technical basic data database 2002, the energy R&D proportion accounted for the R&D budget in OECD demonstrated the downward trend generally (Fig. 1-1), and dropped to under 5% in 1988 from 11.0% in 1981.It was slightly higher than 5% in the last ten years, and dropped to under 5% in 1998. It was 4.3% in 2002. It is the decline that caused the attention of U.S. PCAST. In Nov 1997, the specialized energy committee strengthened energy report that was U.S.A. the challenge of the energy R&D in the face of the 21st century R&D. The suggestion in the report is that the capital cost would rise to 2,400 million dollars in 2003 from 1,300 million in 1997, and increase by 85%. Because the status of energy R&D is very important in Japan and Mexico among OECD countries, so these two countries are exceptional. The proportion of the funds accounted for separately 17.39% and 22.39% in 2001, and was far higher than other OECD countries. According to the preceding calculation, in national R&D funds in 2000 (according to the direct cost of the project counted), the R&D fund of government is RMB 24,664 million. The energy R&D fund is 477 million yuan and accounts for 1.93% of all governmental R&D fund. It is fewer than the half of average level in all OECD countries (4.5% in 2000). Because China is a big developing country, and is at primary stage of socialist market economy, the R&D input ability of energy enterprise has greater disparity compared with OECD country. So over a long time in the future, the government should increase the input into energy technology. According to the situation of OECD countries, 5% of the R&D funds of government should be used for the research and development taking the production of energy and rational utilization as goal. So the proportion of energy R&D funds accounted for R&D budget of our government should be more than 3% in 2010, more than 4% in

2020and had better be up to 5%.

3.5.4. The predicting result

According to the over discussion, from 2000, the energy R&D input of our country in 2010 should be about 25 billion yuan through regarding above-mentioned proportions as the goal and the simple method pushed linear outside, and the input of the government should be about 4 billion yuan. In 2020, the energy R&D input of our country will be about 80 billion yuan, while the input of the government reaches 14 billion yuan. In order to realize the above-mentioned goals (Table 1-3), the average annual amplitude of national amplitude funds should reach 12.9%. And the average annual amplitude of the energy R&D funds should reach 14.1%. The energy R&D funds amplitude of the government should reach 17.3%.

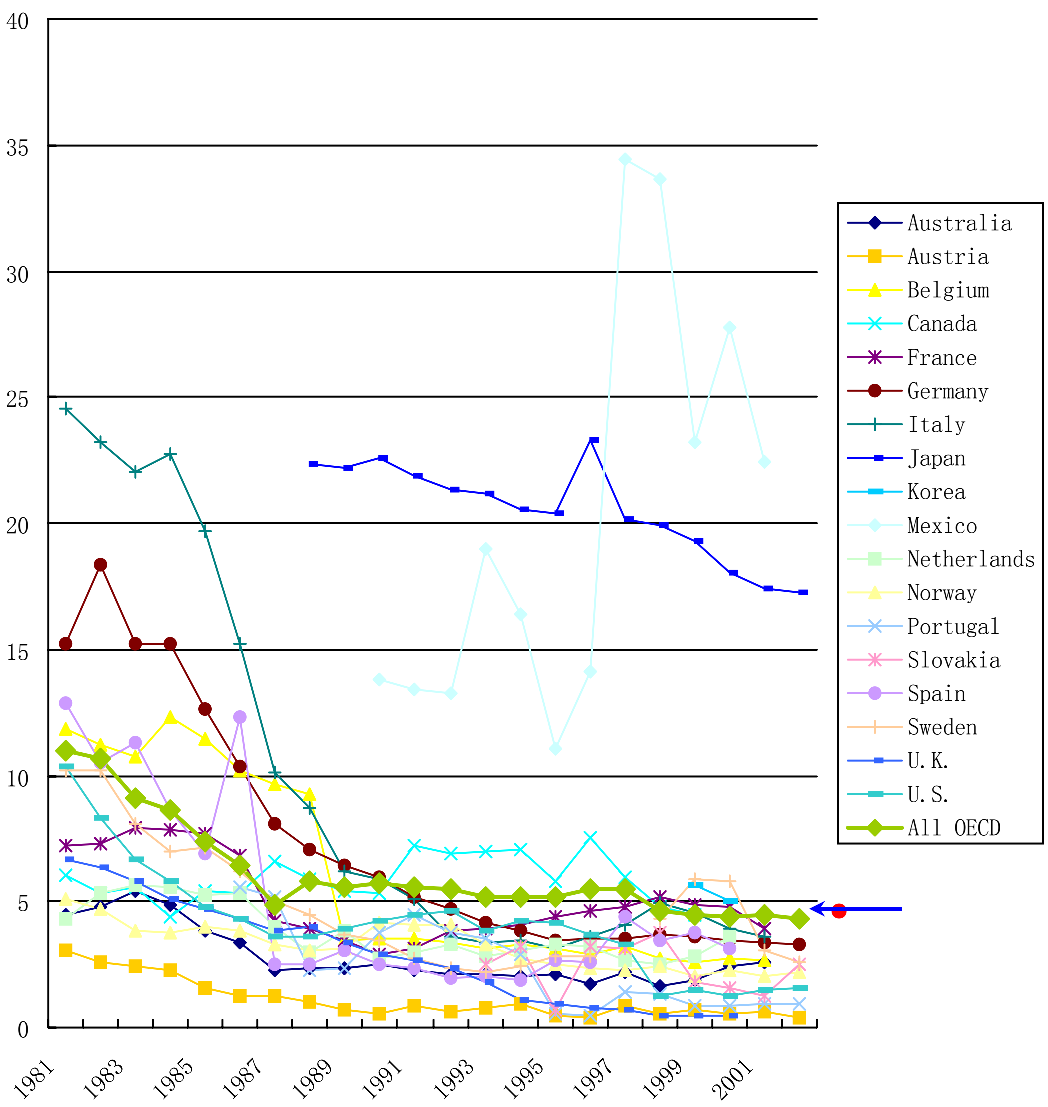


Figure 3- 2 The proportion of energy R&D funds accounting for the national government R&D budget in OECD (BSTS Database 2002)

The source of the materials: OECD, BSTS Database (2002), http://www.sourceoecd.org/

Table3- 12. The calculating tables of energy R&D funds in 2020

Year	GDP (hundred million Yuan)	R&D/GDP (%)	R&D (hundred million Yuan)	R&D funds of government	Energy R&D/ R&D (%)	Energy R&D (hundred million Yuan)	Energy R&D / R&D funds of government (%)	Energy R&D of government (hundred million Yuan)
2000	89566	1	895.7	300.1	6.4	57.6	1.9	5.8
2001	95933.3	1.1	1042.5	346.1	6.5	67.6	2.1	7.3
2002	102840.5	1.2	1213.5	399.2	6.5	79.4	2.3	9.1
2003	110245	1.3	1412.5	460.5	6.6	93.2	2.4	11.2
2004	118182.7	1.4	1644.1	531	6.7	109.5	2.6	13.9
2005	126691.8	1.5	1913.8	612.4	6.7	128.5	2.8	17
2006	135813.6	1.6	2179.8	691	6.8	147.6	3	20.4
2007	145592.2	1.7	2482.8	779.6	6.8	169.6	3.1	24.3
2008	156074.8	1.8	2827.9	879.5	6.9	194.7	3.3	28.9
2009	167312.2	1.9	3220.9	992	6.9	223.6	3.5	34.3
2010	179358.7	2	3668.7	1100.6	7	256.8	3.5	38.5
2010	179358.7	2	3668.7	1100.6	7	256.8	3.5	38.5
2011	192272.5	2.1	4086.9	1217.9	7.1	290.2	3.7	44.5
2012	206116.2	2.2	4552.8	1347.6	7.2	327.8	3.8	51.2
2013	220956.5	2.3	5071.8	1491.1	7.3	370.2	4	58.9
2014	236865.4	2.4	5650	1649.8	7.4	418.1	4.1	67.6
2015	253919.7	2.5	6294.1	1825.3	7.5	472.1	4.3	77.6
2016	272201.9	2.5	6854.3	1974	7.6	520.9	4.4	86.9
2017	291800.4	2.6	7464.3	2134.8	7.7	574.8	4.6	97.1
2018	312810.1	2.6	8128.6	2308.5	7.8	634	4.7	108.5
2019	335332.4	2.7	9054	2553.2	7.9	715.3	4.9	123.8
2020	359476.3	2.8	10065.3	2818.3	8	805.2	5	140.9

4. Discussion about energy R&D programs and policy in China

National policies on energy R&D aim to improve energy R&D level, supply national economic and social development with energy technologies, and promote the commercialization of technology results. Technological innovation in energy is very important to economic development, environmental quality and national security. Technological innovation capacity of most enterprises and regions is rather weak during the transmission to socialism market economy, furthermore, energy technology has the characteristics of big capital input, long innovation cycle, integration and complexity, it is necessary for the national government to formulate unified and steady energy S&T development strategy and programming. National government invests in energy R&D mainly through national S&T program, so energy related R&D programs under the 973 Program, 863 Program and Key S&T Program in the tenth five-year plan are discussed here.

4.1. Energy related programs under the national S&T programs

4.1.1. The National Program for Key Basic Research Program (the 973 Program)

The 973 Program is a basic research plan in support of the national strategically important problems crucial to national important demand, S&T foresight and national long-term development. Energy is one of its important fields, including energy conservation, renewable energy (photovoltaic), efficient utilization of purified coal, exploitation and refining of oil and gas resource, nuclear energy, electricity and fuel cell, hydrogen power etc. Projects under the 973 Program are listed in Table 4-1.

In general, the 973 Program is implemented well and has achieved expected effects. In 2001, important energy improvements included: It is testified by experiments of “Basic Research of Pollutant Control in Coal Combustion” project, that after dealt with a little steam, the efficiency of desulfurization facilities can be raised by more than 30%, even 50%. The result lays a foundation for the desulphurization technology with little water even without water, which is significant to China with insufficient water resource.

Table 4- 1. Energy and /or energy related projects under the 973 Program

Projects	Identification
Key scientific research of disaster protection and control and economic operation of Chinese electricity system	1998
Basic research of coal pyrolysis, gasification and purification at high temperature	1999
Basic research of pollutant control in coal combustion	1999

Research of efficient and clean energy - power system, internal flow in heat – power conversion process	1999
Basic research of improving greatly recovery ratio of oil	1999
Catalytic basis for the optimal utilization of natural gas and coal-bed methane	1999
Basic research on the physics and technology of accelerator driven clean nuclear power system	1999
Key scientific issues of efficient energy conservation	2000
Basic research of volume preparation, store and transportation of hydrogen energy and related fuel cell	2000
Basic research of new cheap and durable photovoltaic battery	2000
Basic studies on formation & distribution of natural gas reservoirs with high abundance and large size and on economic development of gas condensate & gas reservoirs with low abundance	2001
Basic research of new generation internal-combustion engine theory and alternatives for oil fuel	2001
Research on the formation and control technology of M10 from combustion sources	2002
Basic research on formation mechanism and economic exploitation of coal-bed gas reservoir	2002
Basic research of novel and green systems of secondary batteries	2002

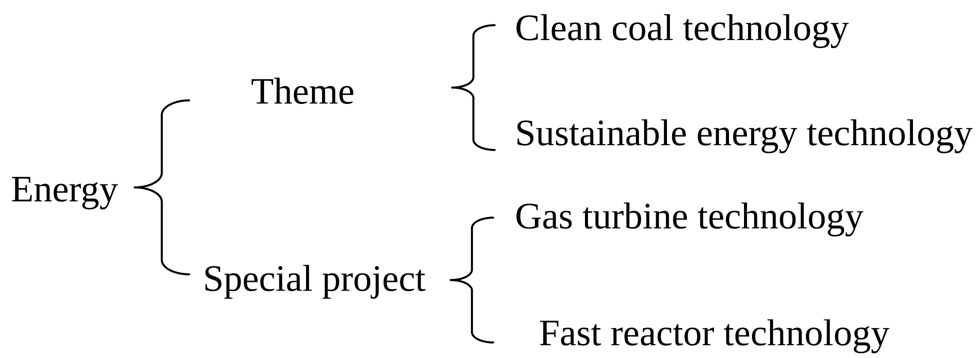
4.1.2. National High-tech Research and Development Program (the 863 Program)

Energy projects under the 863 Program

The 863 Program became a regular national S&T program from the tenth Five-Year Plan. A great deal of preparation has been done before. During the ninth Five-Year Plan, MOST along with China Academy of Science has organized expertise to investigate and demonstrate sufficiently in energy strategic objectives of S-863, inquired broadly related technological personnel, and finished S-863 research report. Having studied international energy technological development trend and Chinese situation comprehensively, four important aspects are put forward such as coal fired combined cycle power generation, coal-based clean fuel production, nuclear energy, renewable energy and energy conservation.

Before the formulation of the tenth Five-Year Plan, MOST carried out prophase research of S&T Development Plan of the Tenth Five-Year and Perspective

Programming of 2015, organized expertise to study specially on key technology problems of manufacturing industry. Energy key technology problems research was among them. Under the 863 Program, two themes and two special projects on energy were established.



Related technologies include:

Clean coal technology;

- coal gasification technology; new coal water slurry gasification, dry pulverized coal gasification with pressure;
- ultra-supercritical coal power generation technology;
- flue gas pollutant control technology of coal combustion power plant;
- design, integration and dynamic characteristic research of IGCC power plant;
- coal gasification power generation technology, multi-productive technology of fuel(raw material);
- coal liquefaction technology.

Sustainable energy technology

Sustainable energy means the sustainable energy system substituting for fossil fuels, including renewable energy, nuclear energy, hydrogen energy and natural gas hydrate.

- direct-cycle helium turbine generation technology of 10MW;
- wind power generating unit technology of MW;
- thin film photovoltaic cell technology;
- efficient biomass gasification electricity technology;
- biomass liquid fuel production technology;
- hydrogen energy technology;
- high temperature fuel cell technology.

Gas turbine technology

including R&D of core components and key technologies of heavy-duty gas turbine to lay a foundation for homemade heavy-duty gas turbine and its commercialization.

Fast reactor technology

To finish the construction and successful operation of fast reactor with thermal power of 65MW.

Implementation of the 863 Program

In 1986, to face the global new technology innovation and high technology competition and quicken the development of domestic high technology and its industry, four scientists including Wang Daheng, Wang Ganchang, Yang Jiaxi, Chen Fangyun brought forward the suggestion to quicken the development of domestic high technology. Deng Xiaoping approved decidedly and initiated The National High-tech Research and Development Program(the 863 Program) that March. General objectives of the 863 program are: to lessen the disparity with developed countries in chosen high-tech with little excellent force, to drive the technology improvement in related fields, to cultivate new generation high-tech talents, to form a foundation for future high-tech industry and national economic and social development to higher level at the end of the 20th century and the beginning of the 21st century.

According to incomplete statistic, in the past 15 years, 6 civil fields of the 863 Program have established more than 230 special research and supported more than 5200 projects, which have achieved more than 2000 items of homeland and foreign patents and released more than 47000 pieces of paper, cultivated nearly 10000 masters, doctors and post-doctors, formed a research personnel with high R&D capacities and some R&D bases with advanced experiment conditions, tested and approved some commercialization bases of the 863 results.

With the support of more than 20 national ministries and commissions and local governments, more than 40000 experts from nearly 600 research institutes, colleges and enterprises have participated in the R&D and organization of projects under the 863 Program.

The 863 Program has contributed much to national high-tech development and economic construction, main results on energy include:

- On December 21, 2000, HTR-10 with totally independent property right reached critical, which meant that China became one of the comparatively advanced countries in the R&D of the 4th generation nuclear energy system. It is worldwide first experimental pebble- bed gas cooled reactor that is designed, manufactured, constructed and operated totally independently, which laid foundation for the leap-frog development of nuclear technology.

- Through applied basic research and international cooperation, domestic fast reactor technology has improved markedly, natrium technique is among world cutting-edge range. CEFR-65 is under construction.

- While the research of fusion-fission hybrid reactor is being carried out in energy field, domestic nuclear fusion research has also been improved, which has laid good technological foundation for the identification of two large-scale Tokamak devices of HT-7U.

During the Tenth Five-Year Plan period (2001-2005), the national government continues organizing the implementation of the 863 Program. Continuing to persist in the principle of doing selectively, the 863 Program gives prominence to strategy, foreground and foresight; Basing on leap-frog and innovation, the 863 Program deals with and promoting the commercialization of high technology; Paying attention to reform the traditional industries with high and novel technologies, the 863 Program aims to promote the adjustment and optimization of industrial structure.

4.1.3. National Program of Key S&T Projects

Facing the main field of national economic construction, National Program of Key S&T Projects aims to tackle the important S&T problems in the economic construction and social development. To adapt to the new situation and new request of national economy, according to the general deployment of National S&T and Education Special Programming during the Tenth Five-Year Plan Period of National Economy and Social Development, MOST formulated Implementation Design of National Program of Key S&T Projects during the Tenth Five-year Plan Period, in which projects on energy were:

- Clean Energy Action -- including construction of demonstration city on clean energy and related policy research, exploitation of commercialization technology on large scale (100MWe) CFB boiler and desulphurization technology and equipment demonstration on flue gas CFB.

- Commercialization of renewable energy technology——including power generated by biomass gasification, large scale biogas power generated by anaerobic fermentation, large scale photovoltaic grid-connected demonstration power plant, large scale photovoltaic air conditioning demonstration system, 750 KW wind power generating unit etc.

- Integration technology exploitation and demonstration of energy saving building and solar energy system -- including complete set of technology of heating and refrigerating by solar energy, PV deployment-building integrated utilization, heat pump utilizing geothermal energy from shallow ground and joint supply system of heating, air conditioning and hot water.

4.2. Comments on energy R&D programs

As stated before, the S&T programs have all established projects on energy R&D, and selected excellent projects according to the principles of impartiality, opening and justness. During project selection, expertise group entrusted by the MOST would consult, advise, supervise and appraise the related development strategy, policy, plan, programming and identification of important projects.

China has also reformed the organization of S&T programs. First breaking the limit of departments and regions, manpower, capital and material were managed and distributed with unification to make greatest use of them; Multi-means of cooperation were carried out among R&D units to pay attention to the projects linkage and results transition; Expertise played a role in consulting, appraising and decision management;

Expertise of young and middle age exerted their effects too; Emphases were laid on projects with expected target products; International cooperation and communion were carried out energetically.

4.2.1. Develop mainstream technologies of energy independently

In general, energy R&D projects under national S&T programs encouraged innovation, paid high attention to enterprises, combined with local, enhanced international cooperation and paid great attention to the import and assimilation of advanced technologies, and has contributed great to overall development of domestic energy industry. The independent R&D of coal water slurry gasification technology by East China university of Science and Technology is introduced here to demonstrate the success of domestic energy R&D programs.

Coal gasification is basic key technology to clean, efficient and integrated utilization of coal. It can produce not only chemical products such as synthetic gas, synthetic ammonia, but also liquid fuels such as methanol, F-T synthetic fuel etc., furthermore, it can also produce gas fuel for power and heating (for example IGCC), urban gas etc. Technology system beginning with coal gasification can realize nearly zero air pollutant and net carbon dioxide emission. Therefore, according to national situation, polygeneration of coal conversion and deep process based on Coal gasification should be the basic path of developing domestic clean coal technology.

There are many technologies on coal gasification, but the commercial operation of IGCC demonstration power plant in the past decade showed that air current bed gasification boiler performed well. Internationally air current bed coal gasification technology has realized commercialization of daily disposing capacity of 2000-2500 tons, net electricity power of 250MW. Air current bed has become the mainstream technology of large-scale coal gasification with the advantage of high carbon conversion rate, good adaptability of coal type and particle size. Representatives among them are Texaco coal water slurry gasification boiler and Shell dry coal gasification boiler.

From 1980s, four sets of Texaco coal water slurry gasification boiler have been imported, maximum daily disposing capacity of single boiler reached 820 tons for the production of chemical fertilizer and methanol, abundant experience of design, construction and operation has been acquired. Because of the continuing R&D for more than a decade years at the basis of the assimilation and absorption of imported foreign technology, it was in 2000 that experimental unit of new coal water slurry gasification boiler with daily disposing capacity of 22 tons was finished creatively and passed the examination operation. Meanwhile, through the deep research into the coal gasification reaction kinetics at middle to high temperature and high pressure in air current bed, it was found that the key factor to the gasification process was heat transfer and mass transfer rate, therefore the multi-muzzle contraposition unit for coal water slurry gasification was exploited, which performed better than Texaco in every technical index at the same processing conditions because of the enhanced striking stream and optimized gasification. This technological result with independent property right means that domestic gasification technology has become internationally advanced. Its direct economic benefit is very notable just considering the saving of patent expense. For example, the patent expense of Texaco gasification unit with daily disposing capacity of 2000 tons is about US$ 8 million.

As compared to the fixed-bed boiler and fluidized-bed boiler, air current bed boiler can develop to maximum scale commercial gasification boiler in shorter period of time, its volume of single boiler is much bigger than other two boilers, so it is easier to be magnified, on which deep analysis and confirmation research has been done. East China university of Science and Technology and Yanzhou Mine Group have brought forward the application for commercialization demonstration unit of coal water slurry gasification with daily disposing capacity of 100 tons, the project has been established under the 863 Program and is carried out successfully.

From the project selection and capital distribution of the 973 Program, 863 Program and National Program of Key S&T projects, S&T programming on energy in the tenth Five-Year Plan has paid more attention to the R&D and commercialization of clean energy technologies, which is coherent with worldwide development trend of energy R&D, this will play far-reaching impact on national economic and social sustainable development. Although there is still quite long way for these technologies now in R&D to realize wide application in production and living, but the independent R&D of new coal water slurry gasification technology and its prospect have shown that it is of great importance to develop mainstream technologies of energy industry independently.

Although in the process of formulating the S&T programs, both the consciousness of developing mainstream technologies on energy independently and capital devotion have been enhanced continually, but due to the restriction from input and certain disjoint between industry policy and S&T policy, we still have a lot to do to develop mainstream technologies on energy.

4.2.2. Increasing inputs in energy R&D are the guarantee for important S&T results.

The importance of energy R&D to result can also be seen from the former example. Key project entitled Exploitation of New Coal Water Slurry Gasification Boiler (multi-muzzle contraposition) was established under S&T program during the Ninth Five-Year Plan period, which was allocated 4.5 million Yuan. On this basis, Institute of Clean Coal Technology of East China University of Science and Technology imported laser-dopler dynamic analyzer by Dantec (DualPDA) at the cost of about 300 thousand dollars. The apparatus played an important role in enhancing the S&T level of East China University of Science and Technology, cultivating research personnel and accomplishing research projects. 13 pieces of paper were released on Physical Review E., Journal of Chemical Industry and Engineering, Journal of Engineering Thermophysics; Four doctors and five masters accomplished total or partial experiment for their degree papers with the apparatus; Several projects under national S&T programs (including Key S&T Projects, 863 Program, 973 Program and Natural Science Foundation etc.) and from enterprises were accomplished using the apparatus; Several items of invention and practicality novel patents were applied, and the patent of Multi-muzzle Contraposition Coal Water Slurry or Coal Powder Gasification Boiler and Its Application has been authorized.

Independent exploitation of four-muzzle contraposition coal water slurry gasification technology has decreased the negotiation price of imported coal water slurry gasification technology from Texaco. In 1996, the patent expense of the technology was 4.2 dollars per Nm^3 $CO+H_2$, after technological communion with East China University of Science and Technology for many times, fertilizer department of Hefei branch of China Petrochemical Industry Company reduced the patent expense to 1.8 dollars per Nm^3 $CO+H_2$ in the negotiation with Texaco.

This case shows that increasing input into energy R&D is very important to the development of domestic mainstream technologies on energy with independent property rights. The choice of key technologies is of more importance when facing the shortage of R&D input.

4.2.3. National S&T programs promote close cooperation between enterprises and research institutes

Compared with foreign large enterprises, most of domestic enterprises are deficient in the R&D capacity, the mechanism that research institutes are out of the enterprises is one reason. Therefore, enterprises technology innovation in implementation, construction of enterprise technology center, technological mechanism reform such as the conversion or mergence into enterprises of technological development institution and Knowledge Innovation Engineering of China Academy of Science have all quickened the reformation. With the support of national S&T programs and commercialization program, the combination of enterprises and research institutes have been enhanced and improved gradually. It is formulated in National 863 Program that the demonstration project should be led by enterprises and implemented by enterprises and capable research institutes together. For example, the project Direct Coal Liquefaction Key Technology was taken charge by Shenhua Group Ltd., and was participated by China Coal Research Institute, Research Institute of Petroleum Processing and Engineering Construction Company of China Petrochemical Industry Group; Yanzhou Mine Company organized the project New Coal Water Slurry Gasification Technology, in which Institute of Clean Coal Technology of East China University of Science and Technology took part. This novel project organization and management mode helps to promote the tight combination of enterprises and research institutes, and it will perfect in the future development. The tight combination of enterprises and research institutes can promote the development of energy equipment industry, as a demonstration of it, Large Scale Domestic CFB Boiler Project can be taken as an example. Reheating CFB boiler of 135MWe was put into operation successfully in Jan 2003, which was the cooperation result of National Clean Coal Combustion Research Center of Tsinghua University and Haerbin Boiler Works Ltd.

4.2.4. Enhance technology forecast research and formulate uniform energy R&D programs.

Energy R&D strategy programming needs to be discussed more widely and deeply. Energy programming needs a longer span, so its R&D programming needs foresight and pre-figuration and should take more long-term work into account. It is unfeasible to do the programming in an onrush, energy R&D programming need constant and continuing technology forecast to base on.

The coordination of and cooperation on the selection and management of energy R&D projects under the 863 Program, 973 Program and National Program of Key S&T Projects have been prominent, since the 863 Program became a regular national S&T program from one of the tenth Five-Year Plan programs. Energy is a complex science and the R&D process of energy production and utilization technologies is a chain hardly detached. Moreover, it is not only a chain, and the complexity makes it possess features of multi chains crossed. Currently in China, an energy technology R&D project is divided directly into basic research, applied basic research, applied research, technological development and commercialization phases, and is assigned to different programs, therefore repeat and overlapping cannot be avoided, and limited resources including capital, technical and management manpower will be wasted. Therein to, the coordination of energy science basic research and energy technology research is the core problem, it can be tackled by converting the management mode of energy R&D.

4.2.5. Insuring the coherence of technology choice and S&T strategy

The development and decision of the national energy S&T development strategy are made mostly in the MOST. Its expert panel consists of the 863 Program energy technology expert committee, the 863 Program expert consulting committee, and the 973 Program expert consulting committee. Project applications are firstly reviewed and selected by technical experts (including a small number of technological economists and management experts). Generally, the experts make evaluation of the applications based on their own working experience and knowledge and following the guideline of the Project Office, which no doubt possesses their limitations. Our study indicates that technology selection and formulation of the strategic objective for the 863 Program and National Program of Key S&T Projects have not been interconnected properly. For example, the projects for coal-combustion pollution abatement technology are fragmented and supported by different government departments with little coordination. The selection of the next generation mainstream coal-based electricity generation technologies is also divorced from its strategy objective as mentioned above. Therefore, insuring the coherence of strategy objective and technology choice can change the current lag and dependence of domestic technology development and innovation, promote the adaptability between the choice of priority technology and the development of national economy and international advanced technology.

There is another issue that should be paid attention in the implementation and management of energy projects under national S&T programs, that is, some expertise not only take part in the identification or appraising of projects, but also undertake the projects, therefore the objectivity and scientific aptitude are deficient in the supervision and appraising of projects, the results of projects are difficult to be guaranteed. The phenomenon of both judge and athlete may be solved by the reform and perfect of management institution of national S&T programs.

4.3. Discussion about policy environment for energy R&D in China

Currently, there are not specific policies on energy R&D. Our discussion is based on the study about S&T polices and industry policies in the energy field. Therefore, the study is rough and exploratory.

It can be found that energy R&D under national S&T programs concentrates mainly on clean energy technology. Therefore, as to the discussion about policies on energy R&D in China, we will mainly study the policies related to clean energy technology. Beginning with the existing policies on high and novel technology, multipurpose utilization of resource and environment protection industry, we will discuss the policy environment of developing clean energy technology,and form the background of studying policies on energy technology, finally try to construct a base for analyzing the policy framework of clean energy technology.

4.3.1. Policy for high-new technology development

In Mar 1991, the State Council passed the Criterion and Methods for the Certification of High and New Technology Enterprises in National High and New Technology Industrial Development Zone. The assured high technologies included energy science and new energy, efficient energy conservation technology, ecological and environmental protection technology etc. The enterprises undertaking the research, development, production and operation related to these technologies and their products can enjoy the national and local preferential policies on tax, finance and credit when they satisfy the essential criteria for the certification.

Preferential policy for high-new technology enterprises

According to Temporary Policy for the National High and New Technology Industrial Development Zone issued by The State Council and Taxation Policy issued by State Administration of Taxation, energy high-new technology enterprises enjoy preferential policies on income tax, import and export tariff, value added tax. That is: After being verified, energy high-new technology enterprises can be collected income tax by 15%; When its export production value accounts for more than 70% of total production value, energy high-tech enterprises can be collected income tax by 10%; Newly established enterprises can be exempted income tax for two years from production year; Joint-venture enterprises with more than ten years of joint operation can be exempted income tax for two years from the profit year; The apparatus and equipment for the exploitation of high technology which can not be manufactured in China can be exempted import tariff; Banded warehouses and banded factories can be constructed in high-tech industry exploitation district, import tariff and import product tax, value added tax can be exempted according to the practical export number; Except product whose export is restricted by national regulations, export products produced by enterprises can be exempted export tax; Enterprises' apparatus and equipment used for the exploitation of high technology and production can adopt acceleratory depreciation; After being authorized, energy high-tech enterprises can establish technology import and export company and foreign branch, enterprises with better export operation can be authorized foreign trade operation right.

Preferential policy on R&D

In recent years, a series of incentive policies on enterprises S&T devotion have been formulated to encourage the enterprises to increase R&D input. Ministry of Finance, State Administration of Taxation have issued Notice on Financial Taxation Policies on Enterprises Technology Improvement in 1996, which suited for state-owned and collective manufacturing enterprises and was carried out from Jan 1st, 1996. Enterprises can enjoy preferential policies on cost calculation, tariff, income tax, depreciation etc. The expense for the R&D of new product, new technology, new technique can be calculated into overhead expenses without the limit of percentage; Key equipment, test apparatus bought for the exploitation of new technology, new product with the cost less than 100 thousand Yuan can be apportioned into overhead expenses once or many times; Enterprises whose R&D expense growth rate exceeds 10% can be deducted another half of R&D expense when calculating income tax. Imported apparatus and equipment for the direct use in scientific research by research institution in enterprises can be exempted value added tax and tariff according to The Notice of Regulation of Free Tax on S&T Things issued by Ministry of Finance and

Customs Head Office; Enterprises' annual net income from technology trade can be exempted income tax temporarily when less than 300 thousand' Yuan; After being authorized, depreciation years of enterprises experimental equipment can be deducted by 30-50% on the basis of national regulation; Enterprises can choose shorter depreciation years from national regulation range according to its technology innovation programming and enduring capacity. All these policies are suitable for energy R&D.

Furthermore, to encourage the technology innovation and development of high technology, Ministry of Finance and State Administration of Taxation have issued new regulations on taxation in Dec 1999, which included mainly: Income from technology trade, technology exploitation and related technology consultation, technology service by Unit and person can be exempted sales tax; R&D expenses for the exploitation of new product, new technology, new technique in unrelated research institutions and colleges supported by social force including enterprises, undertaking units, social group, person and individual businessman can be deducted totally when calculating income tax; R&D expenses in unrelated research institutions and colleges supported by foreign-investment enterprises and foreign enterprises can be deducted totally when calculating income tax according to the regulations of income tax law.

Preferential policy on high-new technology products

Except the products listed in Candidate Import Products That Can Not Be Exempted Tax In Domestic Investment Projects, imported equipments and related technology, matched components, spare parts for enterprises to produce themselves the products listed in National High-Tech Candidate Products can be exempted tariff and import value added tax; Software expenses paid to foreign land related to Imported advanced technology listed in National High-Tech Candidate Products can be exempted tariff and import value added tax; Tax related to exported products listed in China High-Tech Candidate Export Products issued by MOST and Ministry of Foreign Economy and Trade can be drawn back after export according to certain regulations.

To support enterprises and research institutions with the exploitation of new products and commercialization, and to promote technology innovation in enterprises, national government gives special financial subsidy to important new products in certain fields, which has been formulated in Regulation of Subsidy Management on National Important New Products (Provisional) issued by the Ministry of Finance on November 11, 1996. On November 29, 1997, the State Science and Technology Commission, State Administration of Taxation, State Industry and Commercial Administration Bureau, Ministry of Foreign Economy and Trade, State Technology Supervision Bureau, State Environmental Protection Agency, State Foreign Expertise Bureau and Ministry of Labor issued Management Regulation on National Important New Products Plan ([1997] 503). New products plan gave priority to high-tech products, including energy science and new energy, efficient energy conservation products and environment protection products. Credit deduction policy on energy in 1987 was that loan of 60 million from ICBC and ABC (each 50%) by energy conservation office of the State Council were used in the application and popularization of energy technology in countryside, which was raised to 120-130 million in 1996. Central finance supported 50% of the interest with enterprises. Besides the energy special loan in rural area, technology reform special loan of State Economy and Trade Commission were used in developing renewable energy. These policies helped to reduce the production cost through lightening the interest burden of enterprises.

Other related preferential policies

These policies were included in some documents, such as Credit Deduction Management Regulation on Important Domestic Innovation Projects(tried out) (issued by Ministry of Finance and State Economy and Trade Commission and carried out in 1997), Credit Deduction Management Regulation on Technology Innovation Special Loan (edited and issued by Ministry of Finance and State Economy and Trade Commission and carried out on October 27, 1997), Notice of adjusting taxation policies on imported equipments (issued by the State Council in 1997 and carried out on January 1, 1998, [1997] 37) and Credit Deduction Management Regulation on National Program of Key S&T Projects(issued by Ministry of Finance and State Science Commission and carried out in 1998) etc. These policies suited for energy field too.

4.3.2. Policy for multipurpose utilization of resource

Multipurpose utilization of resource includes the reasonable utilization and valuable material's recycle in the process of mining, manufacturing and consuming circulation of the mine resource, such as: multipurpose exploitation and reasonable utilization of commensal mine and concomitant mine in the process of mining; recycle and reasonable utilization of waste residue, liquid waste, waste gas, remaining heat, remaining pressure produced in the process of manufacturing; recycle and renewable utilization of waste and worn material produced in the process of social production.

In Nov 1998, to put preferential policies on multipurpose utilization of resource into effect and enhance the taxation management, State Economy and Trade Commission and State Administration of Taxation formulated and issued Verification and Management Regulation on Multipurpose Utilization of Resource. Preferential policies included:

Building material products whose raw materials include no less than 30% of coal gangue, stone coal and fly coal ash can be exempted value added tax, which suits for building material products produced with other waste residue;

Products whose main raw materials are liquid waste, waste gas and waste residue (listed in Candidate Multipurpose Utilization of Resource) can be exempted or deducted income tax for five years.

4.3.3. Policy for environmental protection industry

In March 1989, Decision on Current Industry Policy Outline by the State Council was issued, in which projects on energy conservation and multipurpose utilization of energy, raw material was listed as important industry, products in technology reform field. In November 1990, office of the State Council transmitted Some Advice on Developing Environment Protection Industry Energetically by Environment Protection Commission of the State Council, in which environment protection industry was listed in priority fields of industry structure adjustment, meanwhile, the definition and connotation of environment protection industry were demonstrated. Environment protection industry was the floorboard of technology exploitation, product manufacture, commercial circulation, resource utilization, information service, engineering contract aimed at preventing and curing environment pollution, improving the environment, protecting natural resource in the national economy. It was decided that coordination group of environment protection industry development was established under Environment Protection Commission of the State Council, which would take charge of formulating general development programming and policies of environment protection industry and entrust State Plan Commission to issue candidate priority products of environment protection industry. After institution adjustment of national government, the work of instructing conservation and multipurpose utilization of resource, organizing and coordinating the manufacture environment protection and the development of environment protection industry has been transmitted to State Economy and Trade Commission. Now it is transmitted totally to National Development and Reform Commission.

In December 1997, the State Council authorized and transmitted Currently Encouraged Candidate Industry Product and Technology, which was formulated by the State Planning Commission. The preferential policy was: imported equipment and technology used in candidate projects themselves can be exempted import tariff and value-added tax after being approved within the scope of equipment and technology expense budget. Moreover, economy management department was required to formulate supportive measures according to candidate to guarantee the effective implementation of national industry policy. Candidate industries included multipurpose utilization of resource and environment protection, such as repair of zoology and environment, multipurpose utilization of resource, multipurpose utilization of solid wastes, multipurpose utilization of liquid wastes, multipurpose utilization of flue waste, multipurpose utilization of waste and used materials, treatment of large-scale liquid waste, monitoring of flue waste, protection of marine environment, etc. Energy industries that could enjoy the preferential policies included: large- and medium-scale efficient coal preparation mills, prevention and cure of gas, smut, mine water, fire under well, coal water slurry, coal gasification, liquefaction of coal industry; solar energy, geothermal energy, ocean energy, garbage energy, biomass energy, large scale wind power, IGCC, clean coal power generation of electricity industry; equipment manufacture with new technology of safe production and environment protection monitoring apparatus, urban garbage treatment technology and equipment, large scale liquid waste treatment equipment, flue gas desulfurization and desaltpetrization equipment in machine industry.

Furthermore, inclined polices to environment industry existed in Instruction Industry Catalogue of Foreign Investor issued by State Plan Commission, State Economy and Trade Commission, Ministry of Foreign Trade and Economy Cooperation at the end of 1997 and Decision of Enhancing Technology Innovation, Developing High Technology, Realizing Commercialization by Chinese Centrality and the State Council in 1999. New industries listed in encouraged catalogue included energy conservation technology, renew and multipurpose utilization technology of resource, environment pollution control and monitoring technology. In Decision of Enhancing Technology Innovation, Developing High Technology, Realizing Commercialization, the necessity of developing environment protection technology and industry, enhancing the development of clean energy clean production and related technology and its industry, realizing the sustainable development through technology progress was pointed out.

Former description, analysis and discussion about policies show that, there have been nice policy foundation and supportive environment for the development of environmentally sound technologies in China.

However, enterprises have little knowledge about the policies, meanwhile introduction and assistance from intermediaries are inadequate either. Therefore the policies have not been fully implemented in reality.

At the same time, the situation has also reflected the need to formulate more concrete and executable policies in order to encourage the uptake of energy conservation and clean energy technology through legislation.

5. Policy recommendations

5.1. Increasing energy R&D inputs

5.1.1. Enlarging energy R&D funding from government

Taking the scarcity of our country energy-supplying and the demands of the clean high efficiency energy for building well-off society into consideration, the proportion of the energy R&D funds accounting for national R&D funds should keep and rise properly, while the national R&D input is improving progressively. This proportion in our country should reach 7% in 2010 and reach 8% in 2020 on the basis of 6.4% in 2000.

The proportion of the energy R&D fund of our government accounting for all R&D fund of government is 1.93% in 2000 and fewer than half (4.5%) of OECD national average level. Our government should increase the energy R&D input. This proportion should be up to 3% in 2010 and not less than 4% in 2020 and have well be up to 5%. So the goal of the energy R&D input in our country is that the energy R&D input our country is around 25 billion Yuan and the government's input accounts for around 4 billion Yuan in 2010. The energy R&D input our country is around 80 billion Yuan and the government's input accounts for around 14 billion Yuan in 2020. To realize the above goal, the average annual increasing degree of R&D funds in our country should be up to 12.9% and the average annual increasing degree of energy R&D funds should be up to 14.1% and the increasing degree of government energy R&D funds should be up to 17.3%.

5.1.2. To make sure the appropriate proportion of energy R&D within the funding of national S&T programs

We should make sure the appropriate proportion of energy R&D within the funds of national S&T programs. It is necessary to arrange reasonably the energy R&D funds in the specific S&T program. According to the energy R&D strategic plans and the demands of our economy development, we should make sure and arrange the appropriate proportion of energy R&D funds in all S&T programs, such as the 973 Program, the 863 Program, National Program of Key S&T Projects and National Natural Science Foundation by making full argumentation. It is the important assurance to determine the energy R&D funds in the S&T programs as a whole for increasing the energy R&D funds from government.

5.1.3. To support R&D of the priority field and national key technology especially

To compare with other countries in the world, especially the developed country, the R&D input is less generally, and the energy R&D level and funds is on the low side in our country. Because the energy R&D has included several fields, in order to make limited resources play a biggest role, our governments should define the limited goal and concentrate advantage resources on solving the key technology in energy R&D during the formulation and implementation of the science & technology plan. The science & technology plan should accord with the national energy strategic request and support the R&D of the priority field and national key technology especially, while it is in the choice of the project and on the distribution of limited R&D funds.

5.1.4. To set up the partnership relation and increase R&D funds together

It is important to set up the partnership relation between government and enterprise, between enterprise and enterprise for the R&D projects that have the high input, the long cycle and the high risk, which implement the R&D mode of shared risks and achievement-sharing. With its developing constantly in depth, the high-tech R&D is characteristic of knowledge-intensive, skill-intensive and funds-intensive and its risk degree increases gradually too. More and more high technology R&D project can not be charged by one organization and even one country independently. For this reason, scientific research institution, enterprise and even the country should launch cooperation, make the investment together, share the achievement, take risks altogether and accelerate scientific findings shift to industrialization on the basis of mutual beneficial and need.

5.1.5. To make full use of international resources for energy R&D activities

We should fully utilize international resources and expand the channel of the energy R&D input of our country. After joining WTO, the chance that our country participates in international scientific and technological cooperation increases greatly. Our country should encourage the scientific research personnel and the R&D organization to participate in the international cooperation in international energy R&D actively, and set up international scientific and technological cooperation project fund in the science and technology plan of our country. On the other hand, our country should attract actively foreign trans-corporation to set up the energy R&D organization in China and to carry on the cooperative research and development of the energy technology. As to enterprise, after joining WTO, the introduce way can receive further development, which is the equipment trade, permit trade, joint-venture trade and cooperative management, international BOT way, technological consultation, cooperative production and franchise operation and so on. Our energy enterprise can choose the rational introduction way and obtain advanced technology with cheaper price in order to raise benefit of the technology import according to the own needs.

5.2. To improve the performance of the energy innovation system in China

Even as national innovation system, the energy innovation system includes the key elements of the system, goals, functions, status and connections. The above-mentioned elements should make harmony with each other, give play to the overall function of the innovation system, and pass the optimization and coordinate of every relevant element in order to reach the macroscopic validity and high efficiency.

5.2.1. Improvement of government management

Energy industry is basic of national economic development, and its R&D course is characteristic of public welfare strong, high input and long cycle and so on. So the energy R&D strategy of government becomes particularly important. American Ministry of Energy issued the strategic plan of American Ministry of Energy in 1997, which indicates that energy R&D plans of the U.S. begin to shift from technology-oriented to strategy-oriented. In 1999, American Ministry of Energy adopted the new R&D package planning method to integrate as one system, which makes the Energy Ministry be able to understand better the balanced situation, the limitation and potential result etc of the plan in order to contribute to improving the plan. But in our country, the research and development work of energy technology disperse in different department and different science and technology plan, which is lack global strategy from the administration to the energy R&D plan, and is apt to produce key cross, omission and repeat in pivotal field between department and plan, and is lack of the whole balance and coordination in the direction, supporting focal point and fund allocation of the energy R&D input. We propose that the government makes the national energy strategy and the energy R&D strategy on the basis of energy requirement forecasting. Meanwhile, the formulation of the energy R&D strategy should confirm the priority area and select national key technology on the basis of the prediction studying on the regular technological.

The national science & technology plan is the basic way that our country implements the macro-level R&D strategy, which includes the energy R&D strategy. But during the management of the science & technology plan, the government should change the function, which is from operating directly roundly the science & technology plan to presiding over the actions, such as setting up the project, allocating, participating in confirming and assessing, and trusting intermediaries to manage course. As a result it can give play to the government function of adjusting and control on strategy implementation and can avoid the government sinking into the concrete affairs and ignore the assurance for macro-level strategy.

The energy R&D should set up the unify and coordinate mechanism between government department and within department, which includes framing the scientific and technological development plan and industry development plan, the exchanges and sharing of the information and the application and popularization of the achievements, and so on.

Specific suggestions include: to set up the combined appraising system of industry policy and S&T policy on energy; to set up a uniform energy S&T expertise group under different S&T programs,whereas in the past there were respective expertise group under different S&T programs; to appoint an administrative official responsible for all energy S&T programs who coordinate with all other S&T officials from different departments of MOST.

5.2.2. Promoting the development of intermediary institutions

Industrial associations, which consider it as their major responsibility to bridge enterprises and government with information swap and conduct academic activities and technology service, and other intermediaries should develop and enhance internal organizational operations within more broad of scope when the government sectors reform and China accesses to WTO. Facing the challenge of international intellectual property rights (IPR) competition, one of the important tasks for the intermediaries is to coordinate member firms' behavior, resolve common problem for the firms within their sector, and formulate the sector's overall IPR planning of for the interests of all firms within the sector. For example, the technology of 300MWe CFB generating unit is under unity organization through the negotiation and bidding to the outside by the domestic main factory union. The long negotiation was organized by the then State Planning Commission. In reality, it can have been organized and implemented by the trade associations.

The government finance should support the forming and protection of the intellectual property rights. But this finance should be favorable to technological diffusion and improve the social benefit of public resources. In order to accomplish the above goal, it is an effective way to give play to the role of employer's organization. Industrial associations should play an important role on promoting government to invest more money on protection of IPR and construction of IPR information network and support applying international patents for key technologies.

It is also needed to set up important coordination mechanisms and play industrial associations' role on settling inner sector dispute and disagreement. Industrial associations should have position in energy innovation system. All government sectors, enterprises and R&D institutes should understand well with the important roles industrial associations play and make full use of them.

From certain meaning, the quantity and quality of the intermediary are scales of the development degree of market economy, especially the development of the small and medium-sized enterprise, which needs the service of the intermediary objectively, such as the hatching and financing service of the enterprise's early days, the consultation, diagnosis, transactions of the property right in the enterprise grow-up, and enterprise listing and investment while expanding etc.. To standardize the service of the intermediary will inevitably promote the small and medium-sized enterprise greatly.

Since scientific and technological small and medium-sized enterprises technological innovation implemented in 1999, it has set up 4069 items altogether, 229 items of energy among them, accounting for 5.6%. It has subsidized 3,010 million Yuan altogether, the energy funds is 163 million Yuan, accounting for 5.4%. If the energy project in small and medium-sized enterprises innovative funds is divided coal, oil / natural gas, energy-conservation, electricity, renewable and new energy system etc. According to field, the energy-conserving project has 79 items, accounting for 1/3 of the total energy items, and the subsidy of energy-conserving project is 53 million, accounting for 1/3 of the energy total funds. As the scientific and technological intermediary, small and medium-sized enterprises innovative fund is playing an active role in supporting the development of medium and small-scale energy enterprise and developing power-saving technology. In order to meet the needs of new situation, this activity should be strengthened further.

The Candidate Projects of Innovation Fund should not be arranged totally according to the key directions of national S&T programs, it should support middle-and-small enterprises more with their technology innovation. Through investigation and study, this research has found that, comparing with existing domestic and foreign technology, an important technology, which is majored in biomass' natural dryness and solidification at normal temperature and is the basic and common technology about production and application of biomass energy, has great characteristic of energy conservation and innovation. But the Candidate Projects are mainly about electricity generation through gasification and liquefaction. Therefore the former project could not be supported with the innovation fund. The work on technology innovation of middle-and-small enterprises should be improved.

5.2.3. Further development of the market function

After china's accession to WTO, China's energy industry will be more and more influenced by the market-based economic system, and the role of market on resource allocations will be continuously reinforced. Establishment of common market regulations compliant with WTO and good order of market on the legal system is great helpful for energy technology flow and R&D investment to energy firms. Energy R&D policy-making must consider well how to play the market function, and how to overcome the obstacles to energy R&D through the market mechanism. Government should pay attention to nurture the market for new energy. It can introduce the formation and development of new energy market. Furthermore, government guidelines can push firms to invest more in clean energy R&D in a market way that is by market pull and inner motivation of firms rather than government push.

5.2.4. Promoting tighter cooperation between enterprises and research institutions

The domestic reform of research institutions in recent years has quickened their system conversion greatly. Based on the domestic and foreign experience, the relationship between R&D institutions and enterprises will influence directly the speed of industrialization and commercialization of R&D results. Many cases have demonstrated that system conversion and mergence into enterprises of research institutions are effective means to improve the R&D capacity of enterprises and quicken the industrialization and commercialization of R&D results. The government should encourage energy enterprises to construct technology center. The improvement of enterprises' R&D capacity can help them to cooperate with research institutions on R&D of advanced technologies. The implementation of national S&T programs has showed that S&T projects are the ligaments between enterprises and research institutions. As a demonstration of it, Large Scale Domestic CFB Boiler Project can be taken as a best example. In the future, we should promote the tighter combination between research institutions and enterprises with national S&T programs further.

5.3. **Enhancement of energy strategy research**

5.3.1. The establishment of energy development strategy should adapt to the needs of constructing middle-class family society completely.

The sixteenth session of NPC brought forward building a middle-class family society that can have advance to all the Chinese. On the basis of optimizing structure and improving benefit, try to let the GDP arrives twice in 2020 then 2000,and realize the modernization on the whole in 2020. This target must have enough energy to guarantee, when 2020, the requirement of one-off energy is about 2400~3200 million criterion coal. The development of Chinese energy, especial to the providing of energy, will face flinty challenge. The constituting of energy R&D tactics should fit to the requirement of building all-around well-to-do society.

We should actualize sustainable development strategy of energy whose character is improving energy efficiency, optimize energy framework, consolidating the intensity of environment protection. The target of R&D tactics should constitute and adjust by this. About the R&D of energy product and providing, should develop the clean coal generating electricity technology, coal liquid burning production technology, oil and natural gas exploitation technology, renewable energy technology and nuclear energy technology.

Reinforce economizing energy and improve efficiency of energy, ameliorate energy providing status. It is very important, that improving the efficiency of energy final using technology should be a very important R&D tactics target in 21st century.

5.3.2. To insist on regular conducting technology forecast research

Technology forecast researches the development of long-range science, technology, economy and society. Its target is finding out the researching domain which is strategic and selecting the technology group which can give the biggest advantage to the economy benefit and society benefit. The basic character of inspecting Technology is collecting viewpoints of different domains experts and public by scientific method of research, and estimating the development direction of technology in the future.

Developing technology forecast in the energy field is not only laying a foundation of setting down the energy tactics, but also pointing out the direction of corporation's tactics projects. We will not estimate the direction of the world's energy development and make mistake in the direction of energy tactics technology if we have no inspecting Technology. Setting down R&D tactics must have the basis of regular inspecting technology, choose the advancing domain of energy research and pivotal technology of country.

The choice of energy technology will influence the route and basic policy of Chinese energy research, it must begin with the energy technology developing level, industrialization level and market, confirm the direction and emphases, set up the joint of research and commercialization, combine the assimilation, absorption, import of foreign technology and independence innovation, grasp opportunity of spanning development, accelerate reforming the conventional energy industry by modernizing technology, cultivate the new point of modernizing energy industry development, upgrade the energy industry organization, improve the whole diathesis and competition of energy industry.

5.4. To strengthen independent energy R&D and develop clean energy technology with high efficiency

5.4.1. Adapting to the international standard

In current years, 60% of our exporting corporation encountered foreign technology vallation, in order to resolve them we must collect the information of foreign criterion, adequately research the criterion of foreign production and analyze the different between Chinese production and foreign, grip the level of international criterion development and importing country's development of technology vallation, improve on our production accordingly. The improving of vehicle fuel criterion requires the oil machining corporation improve their research and epurating technology. The energy efficiency criterion relates to different trade, such as electron, wiring, shipping and so on. In order to adapt to the international criterion, we should boost up production's currency, advantage, credibility and efficiency, relevant corporations should reinforce research in order to their technology level. The items of WTO which are about energy are on the basis of sustainable development. By 2001, in the 19744 terms of country criterions, 8621 of them adopt the international criterion, is 43.7%. In oil trade the percentage is 50%. According to the promises of our government, in 5 years of joining WTO, Chinese technology statute will heighten 10% of which adopt international criterion. Although realize the promises is difficult to our country, in order to accelerate the favorable development of foreign trade, we should increase the percentage of the criterion which adopt international criterion. The government should give policy supports.

5.4.2. Enhancing the legislation of IPR and correlative policy research

Enhancing the protection of IPR is not only one tenet of WTO but also requirement of developing domestic energy technology. In some important domains, the patents we have declared are much less then that of foreign countries, the sequent result is bad. On the other hand, in the precondition of law protecting the IPR, foreign countries can fearlessly convey advancing technology to us and require relevant requiting, this will be a good condition to attract advancing technology. So, we must enhance the protection of IPRs, enhance own innovation and core competition. At present, our law about IPR accord with the TRIPS completely, but, the invigorative system about where the IPR is belong and how to distribute its benefit is still defective.

5.4.3. Constructing good environment of personnel development

After joining WTO, we will drastically compete with the MNC in personnel which means the first resource, the focus is the competing in the contention of technological personnel. According to the rule of WTO, the MNC's locus rule, requirement of canceling local components and localization management, will sharply reduce the international background of corporation. This will actively affect our science and technology development, at the same time, will prick up the competition of technological personnel, will affect the stability of the team of technological personnel. In order to reduce the negative effect of drastic competition, government should build a benign mechanism of technological personnel in our country or in the world. Corporation should improve their competition of technological personnel, not only enhance the system of emolument, but also enhance culturing technological personnel. Only by that could keep the technological personnel.

5.4.4. Promoting the development of clean energy technologies

The production and using of energy relate with the changing of environment and climate of the world, this make the question of environment and climate became a focus. Kyoto Protocol on Climate Change generates a far-reaching effect to the choice and using energy. in the near future, to the supply, exploiting and using low polluting fuel and cleanly energy transforming technology is the keystone; to requirement, the technology of improve energy using efficiency is the keystone. But, at a specified future date, we should open out the technology which is not in market or in the initial stages of business, include: the energy of low or zero exhaust (renewable energy, hydrogen energy, advanced nuclear power), the technology of consuming low energy (such as traffic, illumination) and carbon sequestration technology. The development of cleanly energy is the current of R&D to international energy, is also the requirement of realizing well-to-do society and sustainable development. The core mission of Chinese energy R&D is to develop the cleanly energy technology that can fit to the situation of our country and own to our IPRs. Encouraging new energy, renewable energy and nuclear energy can reduce pollution and the exhaust of greenhouse gas. Developing abstemious energy technology will greatly contribute to reducing pollution and the investment of energy production. It is a basic choice of Chinese energy tactic or science and technology developing tactic to develop cleanly energy. Government should set down the encouraging policy about the using and research of cleanly energy, encourage research institutions and corporations to increase the investment of R&D to cleanly energy and economical energy technology, improve the research capacity of corporation, attribute to the sustainable development of energy. Advice is increasing the investment of cleanly energy in country science and technology project and policy support.

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Appendix A: Main energy scientific research institutions

1. National key laboratories

In 1984, on conditions of the whole strength weakness and the dispersing strength of national basic research, in order to improve the basic research level and realize the goal that the basic research occupies one seat of the world, our country sets up and implements the national key laboratory construction plan specially. In some universities and research institutes, choose the domestic advantageous research field to build a batch of national key laboratories, centralized keen-witted and capable research team, subsidy instrument and equipment construction. It has to be comparatively independent management status and implement the operating mechanism of open,floating,uniting,competition and accept the management of relying on the unit and fixed assessment of the country.

From 1984 to 1993, the country utilized three funds of science and technology to set up and build 81 national key laboratories, invested 910 million Yuan. And utilized the invest of World Bank to set up and build 75 national key laboratories in 1991, invested 86,340,000 dollars and 178 million Yuan. At present, the national key laboratory that is operating is 156, cover most disciplines of the basic research of our country, concentrate a high-quality scientific research team, have a batch of advanced instrument and equipment, undertake all kinds of great scientific research projects of a large number of countries and become force at the core of national basic research.

Table A- 1. National key laboratories about energy science and technology

Techno-field	National key laboratory	Supporting units	Place
Coal	Coal Burning	Huazhong University of Science & Technology	Wuhan
	Clean Coal Combustion Technology	Tsinghua University	Beijing
	Coal Transforming	Shanxi Inst. of Coal Chemistry	Taiyuan
Oil and Natural gas	The oil gas hides geology and the development engineering	Southwest Petroleum Institute/Chengdu University of Technology	Nanchong/ Chengdu
Electric power	Power system and generating equipment control and emulation	Tsinghua University	Beijing

	The electric equipment is electric and insulating	Xi'an Jiaotong University	Xi'an
Energy Saving	Automobile security and energy-conservation	Tsinghua University	Beijing
Impetus	The motive force engineering flows heterogeneously	Xi'an Jiaotong University	Xi'an
	The internal-combustion engine burning	Tianjin University	Tianjin
	Turbulence and complicated system research	Peking University	Beijing

Propelling

2. National great science projects

National great science project means large-scale scientific research device, facilities or network system that is built by the national financial allocations for the basic research and applied basic research purpose. National great science project is the important means to promote the development of national scientific undertaking and launch the basic research. During 20 Years between Sixth Fiver Plan and Ninth Five Plan, government investment is about 2,500 million Yuan. It is at nuclear physics, astronomy, study, living beings, information and so on. And the great science project that is built up already and building is up to more than 20 items. The energy project that has already built up and run is 4 items, and there is one item under construction.

Table A- 2. National great science projects about energy science and technology

Progress	National Great Science Projects	Supporting units	Place
Building up and running	HT-6M controlled thermonuclear reaction device	Inst. of Plasma physics studying	Hefei
	Chinese circulation device HL-1 device	Southwest physics research institute of nuclear industry	Chengdu
	The nuclear heating test of MW 5	Tsinghua University	Beijing
	The high-temperature air cooling test of MW 10	Tsinghua University	Beijing
Under construction	HT-7U super conduction holds Carmack's nuclear fusion experimental provision	Inst. of Plasma physics studying	Hefei

3. Research centers of the national project

In the beginning of the 1990s, the State Planning Commission proposed that building up the research center of national projects should rely on the scientific research institutions, universities and enterprise with scientific and technical result project and industrialization, operating mechanism enterprise and the developing direction market. Up to the end of 2000, the State Planning Commission authorized investing nearly 6 billion Yuan altogether, in which national finance is 2,100 million Yuan and the finance of relevant department and local government is 900 million Yuan. It has built 84 national project research centers. Now more than 70% of these research centers have already changed into limited company or joint-stock company.

According to the preliminary statistics, the research center of national project has transferred nearly 1200 items of scientific and technical result in the past 5 years, implemented technological transfer agreement nearly 2500 and established more than 190 shareholding systems or high-tech enterprises of other types. While it is making nearly 500 national-level scientific and technical results, it obtained the direct economic benefits of nearly 20 billion Yuan too. For example national project research center for cast technology has finished 24 enterprise, 29 items and 137 flow casts to transform online, which gains 40% domestic market of the cast transform online and raise the cast homework efficiency raise by more than 50%. It plays a key role to promote our country continuous casting capabilities from 46% at the end of Eighth Five Plan to present 86%, and increase newly the benefit by 550 million Yuan for enterprise every year.

Table A- 3. Research centers of national project about energy science and technology

Techno-field	Research centers of national project	Supporting units	Place
Coal	Water coal slurry gasification and coal industry	Yan ore chemical fertilizer factory of southern Shandong	Tengzhou in Shandong
	Clean combustion of the boiler coal of hydropower station	Xi'an thermal technology research institute	Xi’an
	Clean combustion of the industry boiler coal	Tsinghua University	Beijing
	Safe practice of the colliery	Chongqing Branch of China Coal Research Institute	Chongqing

Oil and Natural gas	The oil gas exploring software	Geophysics exploration administration of Petro-Chemical Corporation	Zhuozhou in Hebei
	Oil refining craft and catalyst	Petroleum research institute of Petro-Chemical Corporation	Beijing
	The natural gas transforming	Chengdu Inst. of organic chemistry research institute in	Chengdu
Electric power	The technology of power transmission & distribution and economizing on electricity	Beijing Electric Power Research Institute	Beijing
	The power system controls and economical operation	Nanjing power automation research institute	Nanjing
	New-type power	The 18th research institute of Ministry of Information Industry	Tianjin
	Electric electron	Xi'an electric and electronic research institute	Xi’an
	Electric and electronic application	Zhejiang University	Hangzhou
	Vibration of electricity generation by thermal power	Southeast University	Nanjing

4. Research Centers of National Engineering Technology

Since the Eighth Five Plan, the former State Science and Technology Commission (Department of Science and Technology now) begins setting up the research center of national engineering technology, which relies on the key scientific research institutions, scientific and technological enterprises or universities with richer scientific and technological strength, and has more comprehensive the related engineering experimental condition, can offer the comprehensive service and scientific research and development entity contacted with relevant enterprises closely. The purpose is to explore the new way between science and technology and economy, to strengthen the key link that scientific and technical results transform to productivity, and to shorten the cycle that the achievement transformed. While facing the actual need of the large-scale production in enterprise, It improves the maturity, forming a complete set and engineering level of the existing scientific and technical result, accelerates technological transformation of the enterprise, promotes the model change, and offers technical support for introducing, digesting and absorbing foreign advanced technology in enterprises. At present, 103 National Engineering Research Centers have been distributed already in agriculture, energy, manufacturing industry, information, communication, biotechnology, material, construction and environmental protection, development and utilization of resources, light textile, medical and health and so on, which spread all over more than 20 provinces, cities and autonomous regions in the whole country.

Table A- 4. National Engineering Research Centers for energy science and technology

Techno-field	Research Center of National Engineering Technology	Supporting units	Place
Coal	The hydropower station burning	Northeastern combustion technology research center of hydropower station (the burning technique center in Liaoning Province)	Shenyang
	Water coal slurry	General institute of scientific research of coal	Beijing
Solar energy	New energy	Beijing solar energy research institute	Beijing

5. Research institutes under the Chinese Academy of Sciences

Electrical Engineering Research Institute (Beijing), Engineering Therno-physics Institute (Beijing), Guangzhou energy Institute (Guangzhou), the chemical research institute of coal in Shanxi (Taiyuan), chemical physics research institute in Dalian (Dalian), the plasma physics research institute (Hefei).

6. Research institutions in university

There are the research institutes related to energy science and technology in many of universities in China, which is not only the main force to carry out Chinese energy plan of science and technology, but also the basic strength of energy application technology facing market development. Such as heat energy engineering department in Tsinghua University, technological research institute of nuclear energy in Tsinghua University, the institute of motive force and energy engineering in Shanghai Jiaotong University, the research institute of heat energy engineering in

Shanghai Jiaotong University, energy and motive force engineering institute in Xi'an Jiaotong University, the machine and energy engineering institute in Zhejiang University, energy engineering design institute in Zhejiang University, the energy science and engineering institute in China University of Mining and Technology, motive force engineering department in Southeast University, resource and environmental engineering institute in East China University of Science and Technology, energy science and engineering institute in Huazhong University of Science & Technology.