Sustainability Management in China's Hydropower Projects

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Abstract

The sustainable development issues and sustainability management in China's Hydropower Projects are discussed in this paper. The experiences of the hydropower project development in China are reviewed. The sustainable management methods in the Three Gorges Project are described as an example. Some suggestions for sustainable development and management are presented from the viewpoint of sustainability management. People-centered development and management should be promoted in the future hydropower project construction to ensure cost-effective, environmentally sustainable and socially equitable development. Project management/agency (a project management system for public works) should be spread to control project cost and protect against corruption.

Keywords: Project management/agency; Environment; Hydropower project; Participation; Sustainable Development; Sustainability Management; Three Gorges Project.

Status quo of hydropower development in China

There are many rivers in China, of which more than 3000 rivers reserve over 10MW of hydropower energy respectively. According to the 4th national hydropower resources investigation in 1980, the theoretical hydropower reserves in the whole country were 67,600MW, of which the exploitable was up to 37,800 MW. The annual power generation is 1920×10^9kWh, it accounts for 17% of the total worldwide exploitable hydropower resources, ranking the first in the world. The national hydropower resources includes the ample resources of small-size hydropower stations (which means the station with the installed capacity below 50 MW) with the exploitable amount of about 0.128×10^9kWh. The hydropower resources of China are characterized by the following four aspects: (1) The total amount is abundant, but the average amount per capita is low. In term of electric quantity, the resource per capita is only about 70% of the worldwide average. (2) The distribution of hydroelectric power resources is not balanced and the resources are not matched with the economic development. 78% of the hydropower resources are concentrated in the west where the economy is underdeveloped, while 11 provinces and municipalities in the east and coastal areas with developed economy and concentrated population have only 6% of the total, but the electric power consumption accounts for 51% of the total. (3) The water runoff of rivers varies greatly between years and within a year, which bring out difficulty for developing and using hydropower resources. The ratio of the maximum to the minimum annual runoff is 2~3 times for the Yangtze River, Pearl River and Songhuajiang River, up to 15 times for the Huaihe Rive and as many as 20 times for the Haihe River. (4) The development and utilization is not sufficient. At the end of 2003, the developed quantity of the national hydropower is only 24% of the exploitable amount, much lower than the average development degree of 60% of the developed countries. In the coming 20~30 years, China will put priority on the hydropower projects as part of its sustainable development strategy to reduce pollution resulting from burning coal. It is estimated that till 2020, the national installed capacity of hydropower will be 230,000MW (of which the installed capacity of small-size hydropower stations will be 93,000MW). The newly annually installed capacity should be more

than 8000MW. The construction of hydropower will shoulder heavy responsibilities (Suo 2004).

Hydropower project sustainability management

The Beijing Declaration on Hydropower and Sustainable Development adopted at the United Nations(UN) Symposium on Hydropower and Sustainable Development, Beijing, China, 29 October 2004, emphasizes strategic importance of hydropower for sustainable development and promoting hydropower development that is environmentally friendly, socially responsible and economically viable**.** In order to guide the sustainable development of the hydropower projects, some national and international organizations have published their guidelines since the late 1990s. For example, the International Hydropower Association (IHA) published the IHA Sustainability Guidelines in February 2004 (IHA, 2004). IHA regards sustainable development as a fundamental component of social responsibility, sound business practice and natural resource management. Sustainable development is that which meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable development requires the integration of three components - economic development, environmental caution and social justice - as interdependent, mutually reinforcing pillars.

Japan Sustainable Management Award Committee(JSMAC) set up the Japan Sustainable Management Award in 2002, to encourage public recognition of excellent sustainable management in business organizations across the nation. Award applications will be considered without regard to the size or type of organization, and eligibility will not be limited to corporations recognized under commercial law, but will also include other organizations running businesses, such as cooperative societies (JSMAC 2002). Task Committee on Sustainability Criteria, Water Resources Planning and Management of American Society of Civil Engineers published a report on Sustainability Criteria for Water Resource Systems in 1998. The report addresses the need and challenge to reexamine the approaches to water resources planning and management. Water resource systems need to be able to satisfy the changing demands placed on them, now and on into the future, without system degradation. In order to create these sustainable systems, a more holistic and integrated life-cycle approach to water resources planning, development, and management must take place. Such an approach should lead to plans, facilities, and policies that will be physically, economically, environmentally, ecologically, and socially acceptable and beneficial by current as well as future generations. The document examines many of the major issues and challenges raised by the concept of sustainability applied to water resource system design and management. Various suggested guidelines are reviewed including the extent to which they have been applied in the development and management of water resource systems. Some approaches for measuring and modeling sustainability are outlined, and ways are illustrated in which these measures and models might be used when evaluating designs and operating policies. While this manual focuses on the contributions scientists, engineers, economists, and planners can make, it recognizes that the public stakeholders and their political representatives and institutions must also contribute to efficient and sustainable water management (ASCE 1998). The International Federation of Consulting Engineers (FIDIC), published Project Sustainability Management Guidelines (PSM) in 2004. PSM Guidelines address the goals for sustainable development tend to focus on broad problems and issues facing all of society, such as global warming, biodiversity, access to fresh water, and materials and energy use. While this whole-society focus is absolutely essential, it makes it difficult for project owners to clearly define and specify the requirements for sustainable development. In the PSM process, the project owner and the consulting engineer balance the owner’s project vision against cost and available alternatives by working together to select appropriate project goals and indicators for sustainable development which are linked back to higher level goals. Stakeholder input is sought throughout the process. Objectives for sustainable development are therefore addressed in much the same way as other project objectives are addressed in the project’s quality management plan. PSM enables project owners and consulting engineers to devise and customize indicators to meet stakeholder concerns and issues, while demonstrating a rigorous, causal link to the fundamental concerns and goals of sustainable development. The approach can be used by firms to demonstrate both their clients’ commitment and their own commitment to meeting sustainability objectives. PSM also provides a methodology for benchmarking sustainable development project performance, and for ensuring that advances in one dimension of sustainable development are not accomplished at the expense of another. FIDIC is proposing PSM as a new area of knowledge management for use on projects, operating in parallel

to the conventional areas of quality, risk and business integrity management. Firms will be able to add a new dimension of value to their work by helping clients not only apply new and more sustainable processes, systems and technologies, but also demonstrate effectively their contribution to sustainable development in a way that encourages the sharing of knowledge. It also will help establish an environment for innovation so that all parties can cooperate in an atmosphere of openness, transparency and trust (FIDIC 2004). PSM applies the four principles illustrated in Figure 1, 1) innovation ("create an environment for innovation"): anticipate the future, enable information by opening organizational borders and reward information sharing; 2) education ("educate, and be educated"): trust and engage stakeholders and build their capacity to identify issues, include local values and communicate their experience; 3) Improvement ("raise the bar"): continuously improve ways to mitigate resource consumption by seeking new knowledge and information on performance; and 4) alignment ("align globally, adjust locally"): use a core set of indicators traceable to Agenda 21 to align project goals with global goals, while factoring in local conditions (Boswell 2005).

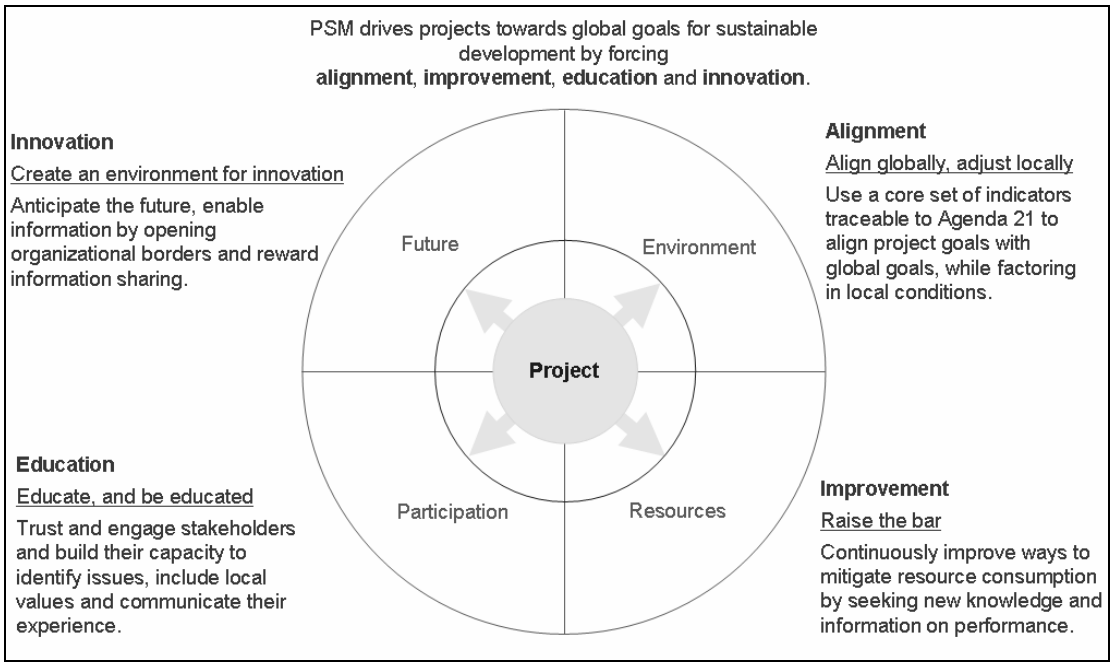

Figure 1. The four PSM principles, innovation, education, improvement and alignment (Boswell 2005).

Experiences and lessons in China's development and management of hydropower industry

China has accumulated rich experiences in successful hydropower development and management, and also learnt a lot of valuable lessons from failures since 1949. They can be summarized as follows:

Establishment of good construction project management system. Before 1980s, the construction of all the hydropower projects in China were controlled under national planning economy with funds allocated by the government and managed by relevant professional government departments in a centralized way. The construction enterprises did the construction and management by themselves and then turned over the projects to the power authorities for management after completion of the projects. Although a lot of hydropower stations were successfully constructed, there were no clear division boundaries among investors, units responsible for projects, construction contractors and operation units with responsibilities either overlapped, disconnected or not clearly designated in the whole system. The investors were not obliged to recover the investment. There was no responsible person for the project with contracting determined by administrative authority, so that there was lack of effective supervision, lack of competition consciousness and the efficiency was rather low. With the reform of national economic system, the planning economy has been transformed to market-oriented economy. A complete set of brand-new management system has been implemented in the hydropower development, that is, to execute project legal entity responsibility system and raise construction fund through multi-channel financing; to carry out bidding and contracting system for introducing competition mechanism; and to implement project supervision system for improving the mechanism of project supervision and management. The legal entity of the project organizes the constructors

by means of contracts, thus establishing a comprehensive and scientific management system to accelerate the hydropower development and construction.

Good planning for river basin and project. In essence, a project planning is a process of getting to know the nature, the river and the community in the river basin, during which a great deal of first-hand accurate data should be collected and necessity and feasibility study be carried out for the selected project in a scientific way. In the decision-making process, the science and democracy way should be used and different opinions should be considered, and decisions should be made on the ground of subjective assumption. Only in such way can accurate and reasonable decisions be reached (Lu 2004).

High quality design and technical management. Full knowledge of the natural conditions of the river in hydrology, geology and earthquake is one of the key elements for ensuring smooth and successful execution of the project. In the process of project construction, strict and scientific management must be exerted, as the construction of hydropower stations is highly subject to the effects of natural and human factors. And due to the complicated technology involved in the project, it is necessary to establish a strict technical management system. The advanced technology and high-efficiency facilities should be employed as much as possible to achieve good performance in construction, and eradicate rashness and disorder in management, which is the key for assuring the prosperous construction of the project.

Sound resettlement policy and action. To do well the resettlement of residents in the reservoir area is also the key that determines the success or failure of a project. China has a large population but relatively small per capita land area, especially in eastern part of the country, where per capita area of cultivated land is only 1.0~1.5 mu (a Chinese unit, 1 mu=0.0667 hectare). For some medium and large-sized stations in southeast coastal areas, the capacity of an annual hydropower generation of 100 million kWh necessitates the relocation of more than 1000 people, and in the western region the figure is about 200 to 300 persons. Some of the stations built in earlier period did not provide sufficient compensation for the relocated people, so the simple and ill-considered relocation resulted in a lot of remaining problems. Since 1980s, the Chinese government has improved the regulations and policies for resettlement of residents in reservoir areas, achieving remarkable achievements by combining resettlement with economic development and with poverty alleviation. A typical example is the Three Gorge Project (TGP). The total number of people relocated reaches 1.13 million. In addition to giving sufficient compensation as relocation funds, preferential policies have been implemented, such as nation-wide counterpart supports and relocation of part of residents to other provinces, which has been carried out simultaneously with the project construction since 1993. Up to June, 2004, the relocation of about 900,000 residents have been fulfilled, among which 165,000 have moved into the plain areas or the economically developed regions. The successful resettlement of TGP shows a good example and is well appraised by relevant UN organization.

Thorough ecologic and environmental assessment. The reservoir constructed for a hydropower station will inevitably change the original state of the river. The ecologic conditions in the submerged area will also be changed to some extent. There are a lot of issues that need to be carefully studied and analyzed, such as whether or not the water quality of the river will deteriorate due to decreased flow velocity, whether the change of aquatic animals' living habits caused will lead to an increase or decrease or even extinction of fishes and what is the mechanism of the river sediment movement, etc. The substitution of hydropower generation by using water potential energy for thermal power by fossil fuel mining and combustion is beneficial to reducing the environmental pollution and is, in general, favorable to eco-environmental protection and improvement. Generally speaking, hydropower development has its favorable side, but also has its unfavorable side. It is necessary to analyze its advantages and disadvantages in an objective manner with emphasis on how to make full use of its advantages and avoid its disadvantages and how to make it beneficial to human's sustainable development. Since 1990s, a lot of hydropower projects have not been approved by the governments due to the environmental issues. For example, the construction of the projects on the Nu River in Yunnan Province has been suspended by the central government in 2002 after the discussions and reviews were made by relevant professional government departments, consultant firms and non-government organization group. The main reason is that these projects have big negative impact on the environment. The mitigation measures should be further considered.

Raising funds from market. A good multi-channel financing and fund operating is the guarantee of funds for project construction. A hydropower project involves the construction of hydraulic structures to obtain primary energy, and manufacturing and installation of hydroelectric equipment to obtain secondary energy. Therefore it necessitates larger amount of investment. In China, the cost for building a 1000MW station is about USD 1000~1200 per kW, with the total investment up to USD 1~1.2 billion. As an example, the total investment in TGP reaches USD 22 billion. The medium and large-sized stations will have a long construction period, normally 5 to 10 years. The price fluctuation and variation of bank interest rates will affect the construction cost of a project, consequently exerting an effect on the competitiveness of its electricity tariff in the power market. For this reason, the risk predictions and analysis should be made continuously so as to avoid and minimize risks, make necessary adjustment in financing patterns and reduce cost by means of "static investment control and dynamic capital operating", thus ensuring the smooth progress of the project.

Rolling development mechanism for a river basin. In the development process, the project legal entity should establish rolling development conception that utilizing the revenue from power generation of the station completed for rolling development of new hydropower projects. The optimum development efficiency can be achieved by means of rolling development on the same river. The development mode can be called as snowball scheme. Typical examples are the development of the projects on the lower Jinsha River and the Qingjiang River which is a tributary downstream of the TGP.

Case study: Yangtze Three Gorges Project

Outlines of TGP. The TGP is the largest hydropower station in the world at present. The dam is located in the areas of Xilingxia gorge, one of the three gorges of the river, which will control a drainage area of 1 million km^2 , with an average annual runoff of 451 billion m^3 . The open valley at the dam site, with hard and complete granite as the bedrock, has provided the favorable topographical and geological conditions for dam construction. Its installed capacity is 18.20GW and the annual average generation reaches 84.7 billion kWh, equivalent to that generated by combustion of 40 million tons of coal. The project also plays an important role in flood prevention and navigation improvement on the Yangtze River. Going through 70 years' course from initial envisage through planning, investigation, design, verification and decision-making, the TGP was eventually left off ground via voting by the National People's Congress in 1992. The huge scale of the project necessitates RMB 90.09 billion Yuan at 1993 price (equivalent to USD 15.74 billion based on the exchange rate in 1993), of which RMB 40 billion Yuan (equivalent to USD 6.99 billion) is used as compensation for the resettlement of reservoir residents, accounting for 44.4% of the total investment. The whole construction period lasts up to 17 years. Taking into account of price factor and interest rate change of banks during this long period, it was predicted in 1994 that the total investment of the project would be RMB 203.9 billion Yuan(equivalent to USD 25 billion). The total population relocated reaches 1.13 million, and 12 new towns are to be rebuilt. Beginning from 1993, TGP has entered its implementation phase. The Chinese government decided to use market economic rules to organize the construction of TGP and established China Three Gorges Project Corporation (CTGPC) as the legal entity of TGP to implement the project legal entity responsibility system. The TGP Construction Fund was set up for injecting capital into CTGPC. The Fund covers about 40% of the total investment, while the revenue from generation will cover 20% and the remaining 40% of capital will be raised from financial market through multi-channels, such as bank loans, public issuance of bonds and corporate listing after restructuring.. After 11 years' construction, the phase objectives like initial impoundment of the reservoir, opening to navigation of the ship lock and power generation of the first batch of units were realized and the relocation of 0.9 million reservoir residents was made in June 2003. Up to August 2004, ten hydro turbine-generator units each with a capacity of 700 thousand kW have been commissioned in the Three Gorges Power Plant with the total output reaching 7 GW and the total energy produced up to 32 billion kWh. It has been approved by the State Commission for Development and Restructuring that, the grid tariff for power generated by Three Gorges Hydropower Plant will be RMB 0.25 Yuan/kWh, not taking into account of 40% allocated to non-profit investment items like flood prevention and navigation, of which cost for operating, depreciation, financing and taxation is about RMB 0.20 Yuan and net profit about RMB 0.05 Yuan for each kWh. CTGPC uses the revenue from generation into the construction of TGP during the construction period. By the end of 2003, RMB 100 billion

Yuan of investment has been fulfilled for TGP. It is predicted that when the project is completed in 2009, the total investment will be controlled within RMB 180 billion Yuan (about USD 22 billion) without exceeding the budget, and in contrary, with some surplus. CTGPC has established via restructuring, China Yangtze Power Co., Ltd., a listed holding company. The “Yangtze Power” was successfully listed in 2003, utilizing the funds raised on capital market for rolling development of new hydropower projects. Now CTGPC has been granted the concession to develop four cascade hydropower stations on the Jinsha River, Wudongde, Baihetan, Xiluodu and Xiangjiaba. The total capacity of these four stations will be 38GW. The preparation and construction of Xiluodu and Xiangjiaba projects have already started. And CTGPC has entered a healthy rolling development period. The whole course of TGP development can be regarded as an example of hydropower development in China by establishing a set of mechanism favorable to accelerating hydropower development (Lu 2004).

Strategy for sustainability management at TGP. In order to fulfill the sustainable development and sustainability management at TGP, the following technology renovation, engineering management measures have been made:

Advanced management system. Many famous internal and international experts are engaged as consultants for ensuring the TGP quality. The international standards and contract documents, developed by International Organization for Standardization (ISO), FIDIC, World Bank, and other international institutions, are employed. For examples, the relevant standards of the ISO 9000 and ISO 14000 families and FIDIC contract documents are used at TGP and the project on the Lower Jinsha River.

River closure and cofferdam in deep water. TGP river closure was conducted on the main channel and the diversion channel, the difficulty is hardly seen in other water conservancy projects. The successful river closure on 11 November 1997 and 6 November 2002 mark that China's river closure technology ranks among the top ones in the world.

Concrete placement at the TGP dam and RCC used for Phase III cofferdam. A M-BOX system is used for placing the conventional concrete at the TGP Dam, and RCC was used for Phase III cofferdam for generation during construction.

High slopes outside the Three Gorges ship lock and metal structures. The double-way and five-step ship lock is characterized by the biggest water head, the most successive steps, the deepest excavation and the highest concreted side slope, and the highest and heaviest miter gate in the world.

Design, manufacture and installation of the generator units. The TGP generator units have the features of large quantity, big capacity, big water head change. Due to their extremely important role in the power grid system, CTGPC has to ensure stability and efficiency of the turbines under high water head, and meanwhile, to take into account the operation performance under low water head. The installed capacity of one TGP unit is 700 MW, biggest in the world. Since the rated water head of TGP units is relatively low, the generators are designed to have maximum capacity of 840 MVA. Therefore, the overall indices of TGP units set new world records.

Development-oriented resettlement. To ensure maximum sustainability for the mega-project, the development-oriented resettlement was made. Allocating about RMB 50 billion Yuan(US$6.1 billion) for resettlement, the governments made huge financial input to help with the industrial restructuring of the project area, aiming to laying a sound foundation for long-term economic development (Bao 2003).

Comprehensive environmental protection. The prevention and alleviation planning for water pollution in Three Gorges reservoir area and upper reaches of the Yangtse River were formulated for implementation. Landslide and other geological hazards were properly handled, full-process tracking and monitoring were conducted to identify in a timely manner any possible adverse impact of the project on the ecosystem and countermeasures were promptly taken.

Establishment of Department of Science, Technology and Environmental protection. A new department responsible for solving the possible problems related to the water pollution, reservoir sedimentation, environmental issues and development of wind generation and solar energy use was established at CTGPC in July 2005. This is first trial at a hydropower company in China.

Suggestions for hydropower project sustainability management

According to the practice of hydropower development in China and the overall requirements of coordinated and sustainable development of current economic and social environment, the following principles should be followed during the development and management of hydropower resources:

(1) Harmonious existence of human and nature. The harmonious existence of human and nature is the core of the strategy of sustainable development, the foregone conclusion of the continued development of economy and society and the natural requirement of the well-developed economy and society. During the hydropower development and management, the relations between social and economic development and natural ecological environment protection, the necessity of development and exploitation and the bearing capacity of ecologic environment, current benefit and long-term interests shall be well disposed. During playing the specific functions of the project, we shall maintain the natural flow regime and the health of rivers as possible as we can. This is the core idea in resolving the water related problems including flood and waterlogging disaster, draught and water shortage, soil erosion and water pollution.

(2) Taking precedence of planning to ensure harmonious development of resources, environment, economy and society. The construction of hydropower project shall comply with the natural law and economic rule, and fully consider the bearing capacities of water resources and hydraulic environment. Within the range of the integrated planning and other strategic plans, we should comprehensively consider and coordinate the overall demands of all regions and all industries, rationally arrange the engineering layout and the development emphasis of the construction of hydropower, strengthen the optimized configuration, appropriate development and high efficiency utilization and effective protection, and ensure the harmonious development of population, environment, resource, economy and society.

(3) Making an overall plan in an integrated development, strengthen management and approving construction plan legally. The interests of the upstream and the downstream, the current benefit and long-term interests and the relation between development and protection shall be taken into the consideration in the development of hydropower resources. Under the conditions of fully considering the development condition of water resources and hydropower resource and the influence of investment and other factors, the hydropower development should be promoted from various aspects, levels and angles in the principle of promoting the beneficial and abolishing the harmful, and comprehensively developing water conservancy, hydropower, water supply and navigation. In the process of hydropower development, the government agencies should examine and approve the construction project according to the relevant laws and the overall factors in the river basin and intensify the supervision in the operation and construction (Suo 2004).

(4) Taking people in the first place and resettling well the immigrant. The hydropower construction always involves in a large number of immigrants and the immigrant-related issues are the key for successfully implementing the hydropower project. Most population affected by the hydropower project is relatively needy, so we shall put people in the first place in the immigrant related works and should take the resettlement and supporting development as an excellent opportunity for the people in the mountainous region to get rid of poverty and expedite their development. Through strengthening the construction of infrastructure and supporting their production activities, we intend to enhance living standard and overall quality of the immigrants, gradually change the backwardness of the resettlement area in society, economy and culture to provide conditions for reaching the moderately prosperous society. The living and production conditions should be ensured and will be improved greatly to make the immigrants share the efficiency and benefit of the hydropower development. On the basis of improving the economic compensation, moving, resettlement, production supporting and other resettlement procedures mainly focus on economy, we should pay much attentions on the sociological issues of the immigrants. We should ensure that the immigrants are

willing to move, live in peace and contentment and are capable of becoming rich. At the same time, we should gradually explore and put into practice the new resettlement mechanism in the condition of market economy and reform the management mechanism of "leading by the government, competent department taking responsible, owner participating and level-to-level management" in national public welfare development project. For the development project by juridical person with independent right of operation, we should explore the system that the judicial person takes the responsibility of immigrant and the new method of investing for immigrants resettlement and overcome the past shortcoming of "judicial person acquiring benefit, the government being responsible of migration and the immigrants failing to share efficiency".

(5)Taxation policy: The power policy focus on coal-fired generation at present, but China should gradually reduce its proportion in the whole power output. We should exert great efforts to develop hydropower and make full use of water energy resources; at the same time, we should accelerate nuclear power construction and actively make commercialized development of renewable energies such as efficient biomass, wind, solar plants. The tax rate for those stations with flood prevention function, wind generation and solar energy should be treated differently from others. As they provide non-profiting public benefits, these stations should be levied at lower tax rate (Lu 2004).

(6)Promoting use of Project management/agency---a project management system for public works: Project management/agency (called as Daijianzhi in Chinese) refers to the project management system that a consultant or project management company awarded by the government organization manages the investment and construction of a public works project as an agent of the government organization. This system is a result of the reform of construction project management for anti-corruption and controlling the project budget less than the planned value in China. The major difference with traditional project management is that the awarded consultants have the right of managing the project investment. The system is adopted in the South to North Water Transfer Project under construction. In order to protect the corruption and control project budget, the system of project management for public works should be spread during construction of the hydropower projects which belong to the public works in China.

Conclusions

The sustainable development issues and sustainability management in China's hydropower projects were discussed. The experiences of TGP were described as an example. Some suggestions for sustainable development and management were presented from the viewpoint of sustainability management.

The status of the global environment requires that as long as hydropower resources are available, we should make the utmost use of this kind of energy and replace the non-renewable fossil fuel generation that aggravates environmental pollution as much as possible. A sound market mechanism is a favorable factor for hydropower development, so we should speed up the reform of power system. People-centered development and management should be promoted in the future hydropower project construction to ensure cost-effective, environmentally sustainable and socially equitable development. The development and management should be equitably met the environmental needs of present and future generations. The advanced management methods such as Project management/agency and project sustainability management should be spread in the hydropower project industry.

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