China, PR: Yang Shu Pu Thermal Power Plant
(Second project in a sequence of projects for the modernisation of coal-fired power plants)

Ex-post evaluation

OECD sector	23020 – Thermal power plants	
BMZ project ID	1993 65 453	
Project-executing agency	China Power Investment Co. (formerly State Power Corp.)	
Consultant	Consortium Steag-IFK	
Year of ex-post evaluation	**2005**	
	Project appraisal (planned)	**Ex-post evaluation (actual)**
Start of implementation	07/1993	11/1993
Period of implementation	66 months	66 months
Investment costs	EUR 184.40 million	EUR 209.80 million
Counterpart contribution	EUR 134.70 million	EUR 154.63 million
Financing, of which Financial Cooperation (FC) funds	EUR 49.70 million	EUR 55.17 million
Other institutions/donors involved	n.a.	n.a.
Performance rating	2	
• Significance / relevance	2	
• Effectiveness	2	
• Efficiency	2	

Brief description, overall objectives and project objectives with indicators

The Yang Shu Pu (YSP) Power Plant is one project from a sequence of projects for the **modernisation of six existing coal-fired power plants located near city centres in China.** The projects of the sequence comprised different project approaches based on proven and tested European techniques for the successive renewal and expansion of the existing power plant facilities. The aim was to gradually reduce the modernisation backlog and to make better use of existing potentials for improvement. In three projects of the sequence the traditional methods used in China to reduce SO_2 immissions were to be employed in a first stage, while flue gas desulphurisation plants (FGDs) were to be installed only in a second expansion stage. In three other projects FGDs were to be installed already in the first expansion stage, while modern power plant and FDG technologies were to be supported in parallel. The common overall objective of the six projects is to improve the supply of electricity and district heat and to contribute towards reducing ambient air pollution as preconditions for the environmentally sound growth of industry and trade in the project regions. The **modernisation project for the YSP power station** is located in the Shanghai project region, and more precisely in the Yang Shu Pu district. The other **modernisation projects** are located in the megacities of Tianjin, Chongqing, Hangzhou and Beijing and in the SO_2 control areas in the greater Beijing and Qingdao areas.

In the context of the YSP project a few thermal power and heat cogeneration techniques hitherto not used in China were introduced. These techniques use for example extraction/condensation steam turbines with better steam parameters and a regulated floating steam extraction pressure (favourable specific coal consumption through the efficient utilisation of the heat capacity of the steam in all conditions of operations). The FC project component covered two 116.5 MW turbine sets equipped

with this technology and two 525 t/h boilers. The objectives of the project are as follows: together with the two remaining blocks of 220 t/h steam capacity using combined heat and power in Yang Shu Pu the power station is to (a) ensure the process steam supply of industrial enterprises and other steam consumers, (b) reduce emissions from the power plant and other decentralised steam generators and (c) contribute to reducing power supply bottlenecks. Currently the second expansion stage is being implemented and a flue gas desulphurisation plant is installed. The following indicators were defined to measure whether the objectives have been achieved:

Indicators to measure the achievement of the overall objective

-- reduction of specific coal consumption per kWh and related specific pollutant emissions (without FGD 345 g/kWh and with FGD 365 g/kWh);

-- high energy efficiency in connection with SO_2 emissions of less than 1,200 mg/Nm3 (without FGD) and dust emissions below 200/Nm3;

-- compliance with Chinese ambient air pollution limits for dust and SO_2 (daily average of 150 micrograms/Nm3);

-- increase in electricity sales as forecast (7.5% p.a.)

Indicators relating to the project objective

-- electricity and district heat generation with FGD (1,750 GWh/a net with two new units);

-- ensuring the process steam supply of industrial enterprises through the two new blocks and two older blocks that continue to be in operation and avoiding emissions from decentralised steam generators through the supply of district steam;

-- reduction of the supply gap (110 MW after deduction of blocks that were shut down or technically obsolete);

-- when the project is finished no more ash is emptied into the river.

In the overall context, YSP has made a greater than expected contribution to achieving the overall objectives in terms of meeting electricity demand, energy efficiency and emissions reduction. The coal consumption of 333 g/kWh net electricity equivalent, which was achieved without flue-gas desulphurisation plant, is lower than the target value. Following completion of the final expansion stage, which began in 2005, YSP will be fitted with a FGD plant. This will further reduce the SO_2 emissions (which were already reduced to 1,200 mg/Nm3 without the FGD) to 90 mg/Nm3. The installed dust filters are clearly better than expected (target: 200 mg/Nm3; actual: 60 mg/Nm3). The project objective of YSP of providing the Yang Shu Pu industrial and commercial area with an improved and cleaner power and district heat supply was achieved (target for two new units: 1,750 GWh/a net electricity equivalent; actual: 2,011 GWh/a). Though the generation of steam is lower than planned, the generation of electricity is higher and on the whole the net electricity equivalent is higher. The reduction in the supply gap is about 33 MW higher than expected at project appraisal. The definition of the project objectives implied the best possible capacity utilisation for centralised process steam and power generation, as far as possible the avoidance of decentralised process steam generation and compliance with ambient air pollution limits. These objectives were equally achieved though with a different relationship of demand for steam and for electricity. The discharge of ash into the river was terminated (target reached).

Programme design / major deviations from the original programme planning and their main causes

China's high economic growth has concentrated on the metropolitan areas, leading to rapidly rising electricity demand for which supply was inadequately being responded to (core problem No. 1) by technically outdated power plant technology (core problem No. 2), with high coal consumption per kWh causing severe air pollution. In the early 1990s, however, it was possible to significantly increase the energy offer with a high level of reliability and very low grid losses using existing infrastructure and the capacities of the surrounding 220/110 kV grid, allowing the supply gap to be closed fast and in a particularly cost-efficient way. The described six modernisation projects each made an individual and pragmatic contribution to solving the core problems by replacing old facilities as far as possible and in a purposeful and appropriate way by two new larger units and modern components.

In the context of YSP two new units were installed to introduce a thermal power technique that has been widely tried and tested in Europe. The project covered two 116.5 MW turbine sets with regulated steam extraction pressure and two 525 t/h boilers. The project conception comprised subsequent possibility of fitting of a FGD right as it was expected that the installation of a FGD would be necessary due to the foreseeable development in the coal and environmental areas and the resulting increasing tightening of environmental protection requirements. The respective measures for fitting a FGD had been taken in due course. Due to the advanced design of the YSP thermal power station with higher efficiency in the high-pressure and low-pressure components of the turbines and the subsequent increase in output by 17% or 33 MW the contribution made to cover the demand for electricity was stepped up. In addition, decentralised coal firing for steam generation was replaced by supplying process steam to new consumers. As expected, measures such as shutting down old facilities and small chimneys, stopping the discharge of ash into the river and using low-sulphur coal, dust filters and high stacks have reduced environmental pollution. In order to reduce total SO2 emissions in Shanghai, which have risen in the last few years, the envisaged final expansion stage was advanced in the time schedule (FGD retrofitting, modernisation of the district heat network and efficiency increases of large-scale consumers).

The total cost for YSP of EUR 209.8 million was 17 % higher than planned at the time of project appraisal. The installed capacity was equally 17 % higher. Foreign currency costs were EUR 55.22 million. In relation to the equivalent net capacity of YSP power plant the specific costs after the FGD retrofitting are similarly favourable as in the case of the FC project “Beijing Thermal Power Station” (the sixth project of the sequence).

Key results of the impact analysis and performance rating

The project objectives underlying the sequence of projects, and also the YSP project, were achieved. The newly created capacities were used to a higher than expected degree and the power plant technology installed to enable lower specific coal consumption was also utilised in other modernisation projects. The power plant sites were secured for the long term and modernised to accommodate future demands. Sulphur dioxide emissions were reduced and, in accordance with the project conception, FGDs will be retrofitted for further sulphur dioxide emissions reduction.

Due to the higher capacity and the improved thermal power technique the YSP project was an effective answer to changes in the demand for power and heat. Moreover, the FGD retrofitting was concluded earlier than scheduled. The YSP project makes a satisfactory contribution to saving coal resources and, thus, to reducing harmful emissions (whereby CO2 is of global relevance; dust, SO2 and NOx are of regional relevance) and to the substitution of district steam supply for ecologically harmful small coal firing plants in the project area. Overall, the effectiveness is satisfactory (sub-rating 2).

The result of the cost-benefit analysis of the modernisation projects is positive because several favourable factors coincided (further utilisation of existing plant components, no additional grid losses; historic design flaws of older components were eliminated; increased capacity with generally lower emissions; investments in efficiency improvements proved to be reasonable as coal prices increased in real terms). Net investment costs per kW net capacity, efficient coal consumption per electricity and heat unit generated (YSP 353 kg/MWh with FGD), good capacity utilisation and availability lead to low specific costs of electricity and district heat supply in the load centre even amid rising coal prices and increasing demands on pollution control (production efficiency). The internal rate of return (allocation efficiency) of 7% to 9 % is good in comparison with the many Chinese power plant projects (600 MW blocks). Overall, YSP has satisfactory efficiency (sub-rating 2).

Using modern power plant technology in the large segment of older coal-fired power plants located at well developed sites near the city centres (40,000 MW installed and 70,000 still to be installed), the project addressed three cause-and-effect chains at the right time that are important for China’s development: reduction of power supply shortages along with very low grid losses, reduction of specific coal consumption to preserve natural resources, and reduction of environmental damage in densely populated areas. The indicators for the overall objective are being met. The technology, which

is established in Europe but in some efficiency aspects new to China, had a model character for the further practical utilisation for modernising this segment of the sector. Since the year 2000 the power plant technology provided through the FC projects has gradually become the Chinese standard for power plant technology. Given China's environmental problems, technology for reducing coal consumption continues to be highly relevant. Overall, the developmental **relevance and significance of the programme are satisfactory (sub-rating 2).**

In summary one can say that due the FC support for a sequence of power plant projects, which were or will be equipped with flue-gas desulphurisation plants at an earlier or later stage, the megacities of Tianjin (YLQ), Shanghai and Beijing will be provided with environmentally friendly and technically advanced coal-fired thermal power stations, which will replace the existing technically obsolete generation facilities over a period of few years. These new thermal power stations will fully comply with the environmental requirements and power supply necessities for a period of more than 20 to 25 years from the date of commissioning of the flue-gas desulphurisation plants. The key figures for the YSP and Shanghai plants are as good as those for the Beijing plant. Overall, after weighing the above key criteria we classify the programme as having satisfactory developmental effectiveness (rating 2).

Conclusions and recommendations

The successful modernisation of the thermal power plants in the megacities of Tianjin (YLQ), Shanghai (YSP) and Beijing is the result of a disproportionately high increase in power generation, the clearly higher efficiency in the high-pressure and low pressure components of modern condensing turbines in comparison with that of the old equipment, reduced captive power demand of the FGDs and, in the case of YLQ, also of the superheating in the steam generation. These efficiency aspects of electricity generation therefore should be given particular attention in comparable modernisation projects.

Legend

Developmentally successful: Ratings 1 to 3	
Rating 1	**Very high or high degree of developmental effectiveness**
Rating 2	**Satisfactory developmental effectiveness**
Rating 3	**Overall sufficient degree of developmental effectiveness**
Developmental failures: Ratings 4 to 6	
Rating 4	**Overall slightly insufficient degree of developmental effectiveness**
Rating 5	**Clearly insufficient degree of developmental effectiveness**
Rating 6	**The project is a total failure**

Criteria for the Evaluation of Project Success

The evaluation of the "developmental effectiveness" of a project and its classification during the ex-post evaluation into one of the various levels of success described in more detail below concentrate on the following fundamental questions:

- Are the **project objectives** reached to a sufficient degree (aspect of project **effectiveness**)?
- Does the project generate sufficient **significant developmental effects** (project **relevance** and **significance** measured by the achievement of the overall development-policy objective defined beforehand and its effects in political, institutional, socio-economic and socio-cultural as well as ecological terms)?
- Are the **funds/expenses** that were and are being employed/incurred to reach the objectives **appropriate** and how can the project's microeconomic and macroeconomic impact be measured (aspect of **efficiency** of the project conception)?

- To the extent that undesired **(side) effects** occur, are these tolerable?

We do not treat **sustainability**, a key aspect to consider for project evaluation, as a separate category of evaluation but instead as a cross-cutting element of all four fundamental questions on project success. A project is sustainable if the project-executing agency and/or the target group are able to continue to use the project facilities that have been built for a period of time that is, overall, adequate in economic terms, or to carry on with the project activities on their own and generate positive results after the financial, organisational and/or technical support has come to an end.