**India: Steam Turbines with Waste Heat Boilers at the Power Plant in Uran**
**Rehabilitation of 4x108 MW Gas Turbine Power Plant in Uran**

**Ex-post evaluation**

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| **OECD sector** | 23062 – Gas-fired power plants | |
| **BMZ project IDs** | (a) 1988 65 446<br>(b) 1994 66 509 | |
| **Project-executing agency** | Maharashtra State Electricity Board (MSEB), Mumbai | |
| **Consultant** | (a) Lahmeyer<br>(b) VEAG Power Consult (formerly IFK Vetschau) | |
| **Year of ex-post evaluation** | **2005** | |
| | **Project appraisal (planned)** | **Ex-post evaluation (actual)** |
| **Start of implementation** | (a) 04/1988<br>(b) 04/1995 | (a) 12/1990<br>(b) 05/1996 |
| **Period of implementation** | (a) 36 months<br>(b) 54 months | (a) 50 months<br>(b) 46 months |
| **Investment costs** | (a) EUR 162.08 million<br>(b) EUR 40.12 million | (a) EUR 279.29 million<br>(b) EUR 40.81 million |
| **Counterpart contribution** | (a) EUR 60.84 million<br>(b) EUR 8.93 million | (a) EUR 121.39 million<br>(b) EUR 27.75 million |
| **Financing, of which Financial Cooperation (FC) funds** | (a) EUR 101.24 million<br>(b) EUR 31.19 million | (a) EUR 157.90 million<br>(b) EUR 13.06 million |
| **Other institutions/donors involved** | n.a. | n.a. |
| **Performance rating** | 3 | |
| **• Significance / relevance** | 3 | |
| **• Effectiveness** | 3 | |
| **• Efficiency** | 4 | |

**Brief Description, Overall Objective and Programme Objectives with Indicators**

Both Financial Cooperation (FC) projects centered around a gas turbine power plant in the vicinity of the city of Uran, some 70 km south of Mumbai, operated by the Maharashtra State Electricity Board (MSEB). The project 'Steam Turbines with Waste Heat Boilers in Uran' comprised the delivery and installation of four waste heat boilers and two 120 MW steam turbines to utilize the waste heat from the four 108 MW gas turbines that were already installed. As a result of the restructuring the power plant was equipped with two combined gas-and-steam turbine units of 336 MW each. The follow-up project 'Rehabilitation of the 4x108 MW Gas Turbine Power Plant in Uran' comprised the delivery of spare parts to rehabilitate the four gas turbines in the combined system as well as consulting services to eliminate deficiencies in the operational management of the MSEB. The overall objective of the project 'Gas Turbines with Waste Heat Boilers' was to improve the conditions for the macroeconomic development of the western region. This was to be achieved by contributing to reducing the regional power supply deficit (project objective). The overall objective of the follow-up project was to contribute to macroeconomically efficient supply with electric power. The project objectives were to make a sustained improvement in the availability and in the use of the capacity of the Uran power plant (by using waste heat).

No indicators were defined to measure achievement of the overall objective of the project 'Gas Turbines with Waste Heat Boilers.' The indicators set to measure achievement of the overall objective of the follow-up project were: (i) cost recovery ratio of at least 65%; (ii) share of the rising demand for power attributed to consumption does not exceed 40%. The indicators defined to measure achievement of the project objective of the project 'Gas Turbines with Waste Heat Boilers' were: (a) overall efficiency of the combined system of at least 43% (48%) once it begins operating; (b) annual power supply of at least 1,950 GWh (2,000 GWh) per turbine unit once they begin operating; (c) share of power for productive purposes in the region is approx. 70% two years after operation begins with an increase in overall consumption of 8-10% per year. The indicators set to measure achievement of the project objective of the follow-up project were: (d) availability of the power plant at least 75% of the time after completion of the rehabilitation work.

**Programme Design / Major Deviations from the original Programme Planning and their main Causes**

The Uran power plant was built from 1980 until 1986 for peak load and medium load operation. It initially comprised three 60 MW gas turbines and four 180 MW gas turbines. Three of the 180 MW gas turbines installed during this period were financed out of FC funds. The power plant was designed in such a way that it could be upgraded later on to an integrated gas and steam turbine plant for minimum load operation. The provision of more power was assured through the expansion of the 220 kV switchboard and corresponding overhead lines. Simultaneously the grid in the western region was built up with the help of funds from the World Bank. When gas deliveries totaling 3 million cubic meters per day (MMCMD) were promised to the Indian government in 1987, the MSEB decided to combine the four 180 MW gas turbines with waste heat boilers and two turbogenerators in order to use the steam being produced. This formed the basis for the FC project 'Steam Turbines with Waste Heat Boilers' that was initiated in 1988. Since the remaining economic life of the gas turbines decreased faster than expected owing to difficulties with repairs and maintenance, in the year 1994 there was an urgent need to increase their economic life via renewal measures in order to have another 100,000 equivalent hours of operation. These measures were implemented under the follow-up project "Rehabilitation of Four 180 MW Gas Turbines."

The project 'Steam Turbines with Waste Heat Boilers' comprised the turn-key delivery, installation and start of operation of four waste heat boilers for the four preexisting 180 MW gas turbines and two new 120 MW steam turbines with generators, including auxiliary systems, air condensation systems, a water treatment system, the necessary electronic equipment, transformers, instrumentation and control technology including a control room, buildings for the administration and the workshop, and consulting services. As planned during the project appraisal, the project design was optimized: All adjustments of the design, such as the cancellation of alternative fuel supply via oil, were justified and have proven to be correct. The result of the project is a functioning combined system comprising two 336 MW units with a maximum overall efficiency of 47.5%.

The project 'Rehabilitation of Four 180 MW Gas Turbines' comprised the procurement of packages of materials to rehabilitate four 180 MW gas turbines, plus consulting services. The additional delivery of two mixing chambers was financed out of remaining funds from the preceding project 'Steam Turbines with Waste Heat Boilers.' During project implementation numerous changes were made to the rehabilitation measures proposed during the project appraisal to take the actual condition of the turbines and the identified extent of the damages (losses) into account, to comply with the project-executing agency's requests for spare parts or to resolve problems with obtaining approvals. Despite the changes regarding the packages of materials, as a result of the project all measures required for the extension of the economic life of the turbines were applied, key spare parts needed to ensure the plant's availability were procured, and the maintenance capacity of the project-executing agency was improved.

The planned consulting services for the MSEB that were planned as a submeasure of the rehabilitation project in order to improve the operational management of the Uran power plant were not performed. The contract concluded in 1998 between the MSEB and Siemens for the introduction of a modern, computer-based operating system was cancelled by Siemens by mutual consent after irreconcilable difficulties arose between the contracting parties prior to project implementation. The contract concluded with VEAG Power Consult for the performance of risk analyses and security audits to analyze and resolve breakdowns at the power plant were carried out as planned, however. The five security audits that were conducted confirmed the positive impact of the rehabilitation measures on the economic life and the availability of the turbines and made it possible to specify recommended action to avoid breakdowns in the future.

The preliminary indicators of achievement of the project objective that had been defined during the appraisal of the project 'Steam Turbines with Waste Heat Boilers' were increased during implementation in terms of overall efficiency (from 43% to 48%) and of annual power produced (from 1,950 GWh to 2,000 GWh). This adjustment was to take account of the improved overall efficiency of the plant made possible by the optimized design.

In early 1989 Lahmeyer International was contracted by the MSEB as implementation consultant for the project 'Steam Turbines with Waste Heat Boilers' following a tender limited to Germany. The revision of the project planning by Lahmeyer revealed some substantial changes in the system design as planned by the MSEB and the Central Electricity Authority (CEA). Following the tender for the power plant that was conducted in June 1989 and limited to Germany, it was revealed that earlier estimates of the project costs were far too low (due to the extent of the design changes that were ultimately necessary). Despite further changes to the system concept in order to cut costs, the committed funds had to be increased in late 1990 by EUR 57.3 million to finance the unavoidable additional expenses. The contract for turn-key delivery and installation of the system components was awarded to Siemens AG in October 1990. Siemens, in turn, involved 29 Indian and German companies in the project through subcontracting. Work began in early 1991 and ended in January 1995 when the second combined unit began operating. The project implementation period was 50 months and thus 14 months longer than the total period projected during the project appraisal. The 14-month prolongation was caused by long approval and customs clearance times, supply bottlenecks at Indian companies, unrest and strikes, financial difficulties of subcontracted firms, and breakdowns at the power plant.

The rehabilitation measures under the follow-up project were implemented as planned, i.e. largely independently of the MSEB. The project was implemented faster than scheduled at the time of the project appraisal despite a one-year delay in the conclusion of the contract that was unforeseen and was caused by changes in the project design. The last turbine began operating in March 2000. The total project implementation period was 46 months and was thus 8 months shorter than presumed during the project appraisal. However, the service contract agreed with Siemens for the introduction of a computer-based operational management system did not take effect. Owing to these problems the performance of the security audits for which VEAG Power Consult had been contracted took longer than expected. The last of the five security audits was not conducted until late 2002.

**Key Results of the Impact Analysis and Performance Rating**

Overall it can be said that the two FC projects made an important contribution to stabilizing power supply in the project region. Although power bottlenecks are, as was the case during the appraisals of the two projects, still a major obstacle to the region's economic development, there is no doubt that if the FC projects had not taken place, the supply gaps would have been much greater, with all the corresponding consequences for economic development in the region.

From a microeconomic point of view as well both projects ended up being an extremely beneficial alternative investment. Against the backdrop of high grid losses that had not been identified as such during the project appraisal, from today's point of view it would have been recommendable to introduce measures to reduce grid losses along with the measures to expand the production capacities.

The projects generated both direct and indirect employment effects. The direct effects are limited to the short-term assignment of local construction workers and additional staff hired at the power plant. The project contributed indirectly to maintaining jobs in industry and agriculture that would have been at risk had the power supply deficit been greater.

The projects promote energy-efficient technology (use of waste heat to generate electricity) and the use of a comparatively clean fuel (gas).

Based on a combined assessment of all impacts and risks described above, we have arrived at the following rating of the projects' developmental effectiveness:

Effectiveness

The objective of the project 'Steam Turbines with Waste Heat Boilers' was to contribute to reducing the power supply deficit in the western region. Improving the use of local resources (natural gas) was a secondary objective. The objectives of the follow-up project 'Rehabilitation of Four 108 MW Gas Turbines' were to sustainably improve the availability and the use of capacity of the power plant in Uran (by using waste heat). Measured against the indicators, the project objectives were achieved to a sufficient extent: owing to bottlenecks in gas supply, the overall efficiency of the combined system averaged 43% and thus did not reach the maximum indicator of 47.5%. Better use of capacity and a simultaneous increase in overall efficiency would only have been possible if the gas supplier had continually delivered the quantities of gas required for full-load operation. Taken together, during the past 11 years the two combined units attained a rate of utilization of capacity of 68% and thus exceeded the target set for the project of 66% (1,950 GWh). The share of total consumption attributed to productive consumers was 82% and thus far higher than the indicator of 70% for the supply area of the MSEB and for the region. The indicator of achievement of the project objectives defined for the follow-up project 'Rehabilitation of Four 180 MW Gas Turbines' (i.e. availability of at least 75%) was achieved by a safe margin. As of 1996 the availability of the combined system was considerably above 75%. Therefore, we classify the effectiveness of both programmes as sufficient overall (sub-rating: 3).

Relevance/Significance

The overall objective of the project 'Steam Turbines with Waste Heat Boilers' was to improve the conditions for the region's macroeconomic development. The overall objective of the follow-up project 'Rehabilitation of Four 108 MW Gas Turbines' was to help provide electric power in an macroeconomically efficient manner. No indicators were defined to measure achievement of the overall objective of the project 'Gas Turbines with Waste Heat Boilers.' The indicators set to measure achievement of the overall objective of the follow-up project were: (i) cost recovery ratio of at least 65%; (ii) share of the rising demand for power attributed to consumption does not exceed 40%. The indicators set for both overall objectives were attained to a sufficient degree: In the period 1985/86 – 2003/04 28.3% of the increase in consumption was attributed to consumption of power, and the macroeconomic cost recovery ratio exceeded 65%. Both projects proved to be beneficial investment projects on both the microeconomic and the macroeconomic level in that they contributed substantially to expanding the power plant park of the MSEB at minimal cost. However, their contributions to economically efficient power supply are clouded by high technical and non-technical system losses (approx. 36%), the actual scale of which was not discovered until the regulatory authority MERC got involved. From today's point of view, in addition to expanding the production capacity measures to reduce the technical and non-technical grid losses would have been an urgent necessity. The activities of the regulatory authority MERC, which took up its work in the year 1999, had a positive impact. Diverse measures introduced by the MERC led to a significant improvement in the transparency of the electricity sector in Maharashtra (incl. discovery of the actual quantity of system losses), and some key measures encouraged the economic recovery of the sector. These measures included adjustments in the tariff structure, measures to reduce system losses, the decentralization of the MSEB etc. Therefore, we classify the relevance/significance of both projects as sufficient overall (sub-rating: 3).

Efficiency

Due to considerable cost increases, the specific costs of both projects amount to EUR 476/kW of installed capacity. In view of the remaining economic life of the combined system of 15 years, we consider this acceptable. The internal dynamic production costs of EUR 22.08/MWh, which correspond to INR 1.21/kWh (discount factor: 10%) are low given the local context. However, from today's perspective consistent measures to reduce the very high technical and non-technical losses would have been a key component of a cost-efficient expansion strategy for the electricity sector. In light of this we consider the production efficiency to be slightly insufficient. In view of the internal cost coverage ratio of nearly 100% and the collection rate of approx. 90%, we consider the allocation efficiency to be sufficient. Overall, we rate the projects' efficiency as slightly insufficient (sub-rating: 4).

In consideration of the sub-criteria mentioned above, we rate the developmental effectiveness of the projects as **sufficient** overall (**rating 3**). Despite non-adherence to the operational appraisal criteria for the energy sector (grid losses of 36%), the positive sector reforms and the consistent progress made by the regulatory authority MERC in the past 6 years in increasing the profitability, efficiency and transparency of the electricity sector in the state of Maharashtra played a decisive role in our assessment.

## General Conclusions

If the overall sector conditions are unfavourable, investment projects in the electricity sector should be supported under Financial Cooperation only if the partner country is consistently and credibly committed to implementing reforms to improve sector performance (operational appraisal criteria as a benchmark).

The promotion of electricity projects under FC should strictly focus on the operational appraisal criteria for the energy sector.

## Legend

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| 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 design)?
- 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, organizational and/or technical support has come to an end.