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AGENCY FOR INTERNATIONAL DEVELOPMENT

EVALUATION OF THE HYDROELECTRIC DEVELOPMENT PROGRAM

OF

KYRGYZSTAN

EXECUTIVE SUMMARY

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Introduction

Hydroelectric energy potential is the most important indigenous energy resource in Kyrgyzstan. Over 80 percent of the country's installed generating capacity, and a similar percentage of total annual electric energy generation, derives from hydroelectric resources. Furthermore, developed hydroelectric capacity represents less than 11 percent of the total development potential.

The exploitation of this important resource has therefore been a high priority of the governing authorities since the mid 1960's, when a program was commenced to develop hydropower facilities in the Naryn river basin which covers a substantial portion of the country's geographic area. The first phase of this program included the development of the Lower Naryn river with the construction of the large Toktogul reservoir and four downstream projects. This phase is now being finalized with the completion of the Tashkumir and Shamaldisai projects. These projects have an ultimate installed capacity of 2,770 MW and an average annual energy generation of 10,000 GWh. However, their operation is driven by irrigation releases in the summer, with the result that summer energy production exceeds Kyrgyzstan's internal demand. On the other hand, the demand for electricity is at its highest in the winter, and a second phase of development -- planned before the breakup of the Soviet Union -- was to develop sites upstream of the Lower Naryn projects to meet this demand, starting with the Kambarata projects. However, the transition of the Central Asian republics to sovereignty and market-based economies has necessitated a postponement of this development phase, pending an updated assessment of electricity demand, costs and benefits, and financing potential.

The present studies are thus a part of the Kyrgyzstan State Energy Company's program to determine and pursue the optimal development of the hydroelectric resources of Kyrgyzstan. This over-riding objective is accomplished through performance of the following major tasks:

- *Review of the electric power market demand,*
- *Review of the most promising upstream sites: Kambarata, Kirov and Upper Naryn projects,*
- *Development of new construction cost estimates,*
- *Performance of reservoir operation studies and economic evaluations, and*
- *Making recommendations bearing on the operation and expansion of hydroelectric facilities.*

Funds for this study were provided by the United States Agency for International Development (USAID). Throughout the study, excellent technical coordination and cooperation was provided by the personnel of the Kyrgyzstan State Energy Company (KSEC) and the Tashkent Hydro Design Institute (THDI).

Electric Power Sector

The Kyrgyzstan State Energy Company (KSEC) is responsible for electrical power generation in Kyrgyzstan. It is a state-owned enterprise under the authority of the Ministry of Energy. Plans are underway for the KSEC to become a joint-stock company. It currently operates 20 generating stations with a total installed capacity of 3,414 MW, of which 2,740 MW or 80 percent are from hydropower facilities, and 674 MW are from two thermal powerplants which are also used for district heating in the cities of Bishkek and Osh.

The hydropower facilities of the Naryn river are concentrated in the lower reaches. Figure 1 shows a profile of the Lower Naryn with the location and installed capacities of the existing hydroelectric stations and proposed Kambarata projects.

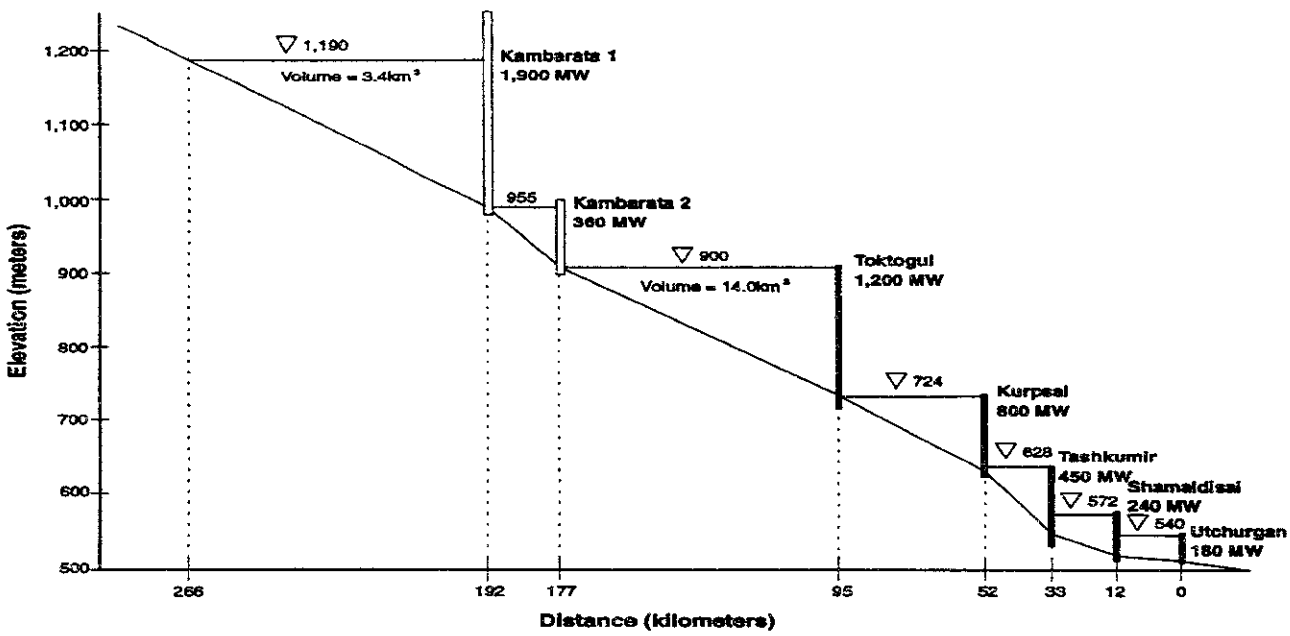

Figure 1: Existing and Proposed Hydropower Projects on the Naryn River

In 1992, Kyrgyzstan's total electricity production was 11,793 Gwh, 78 percent of which was generated by hydroelectric facilities. The peak demand is in December or January, while summer demand is about 60 percent of the winter peak. In 1992, the peak power demand was about 1,850 MW. Figure 2 shows the 1992 monthly distribution of energy consumption.

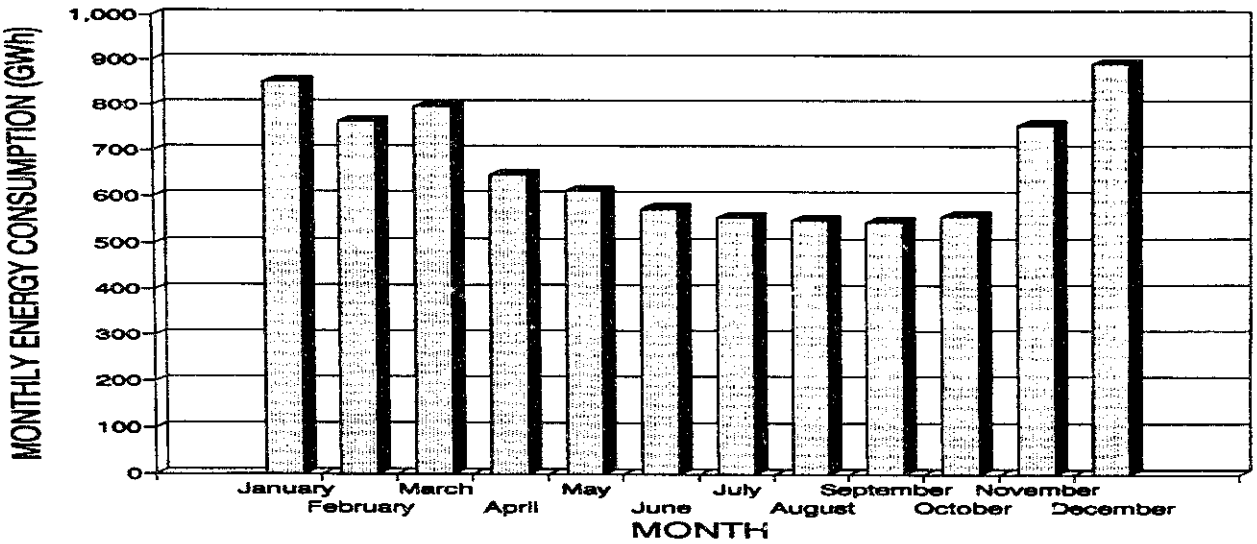

Figure 2: 1992 Monthly Distribution of Energy Consumption

Historically, reservoir release for hydropower generation has been dictated by irrigation demand which is highest in the summer, and excess hydroelectric energy is exported to other Central Asian countries via a 500-kV transmission grid that interconnects the countries of Turkmenistan, Uzbekistan, Tadjikistan, and Southern Kazakhstan as shown below on Figure 3.

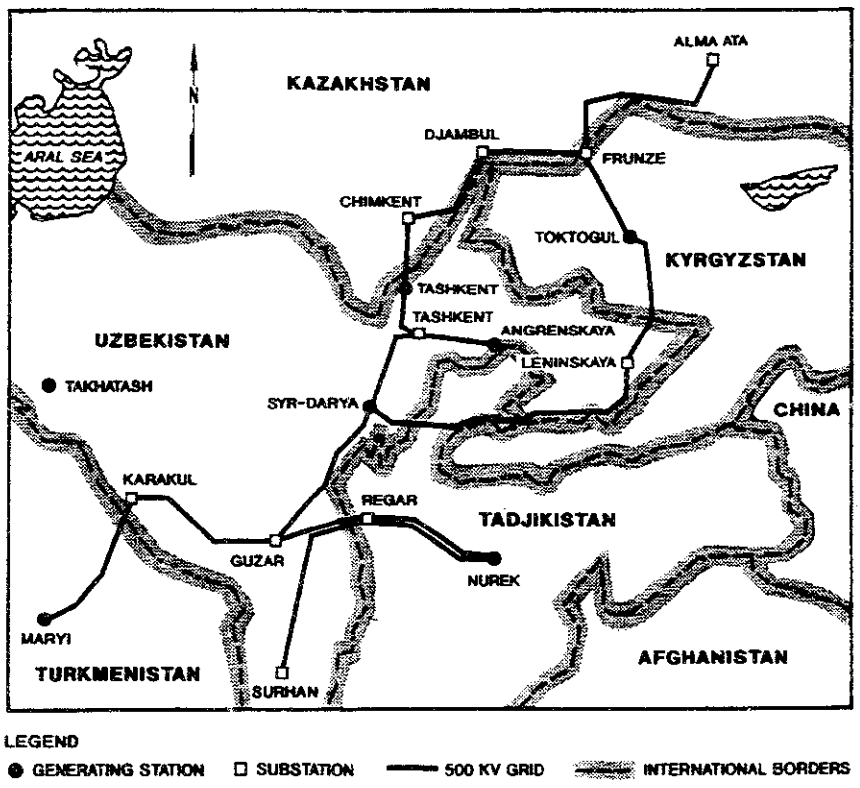

Figure 3: 500-kV Transmission System of Central Asia

Net annual exports from Kyrgyzstan averaged about 5,000 GWh during the period 1988-1991, but have been reduced during the current period of political and economic transition. In 1992, exports were only 2,176 GWh.

Electric Power Market Demand

The evolving economic and political realities facing the former Soviet republics have affected current energy demand and future economic growth. In the electrical sector, recent declines in industrial consumption have been more than offset by a major increase in residential demand. Fuel prices (coal, gas or oil) have greatly increased over the past two years to approach world free-market price levels, while the price of electricity has remained very low. This has resulted in a shift towards electric heating appliances and a 75 percent increase in residential demand between 1990 and 1992. This trend has continued over the first six months of 1993.

To reflect the current uncertainties of the short- and long-term economic forecasts of Kyrgyzstan and of the power exchanges between the various republics of Central Asia and the surrounding countries, three scenarios were developed. These scenarios -- designated High Growth, Moderate Growth, and Low Growth -- were developed for the period 1993-2010 to show the range of potential demand. The energy forecast developed by the Republic of Kyrgyzstan was assumed as a "High Growth" scenario. The two other scenarios were based on revised assumptions underlying the High Growth scenario, involving duration of economic contraction and strength of eventual recovery, various forecasting methodologies, and historical trends; and discussions with representatives of the electric power sectors of Kyrgyzstan, Kazakhstan and Uzbekistan. The internal demand of Kyrgyzstan was analyzed separately from subsequent projections of the export market. Historical data and projections for the energy consumption of Kyrgyzstan are shown graphically in Figure 4.

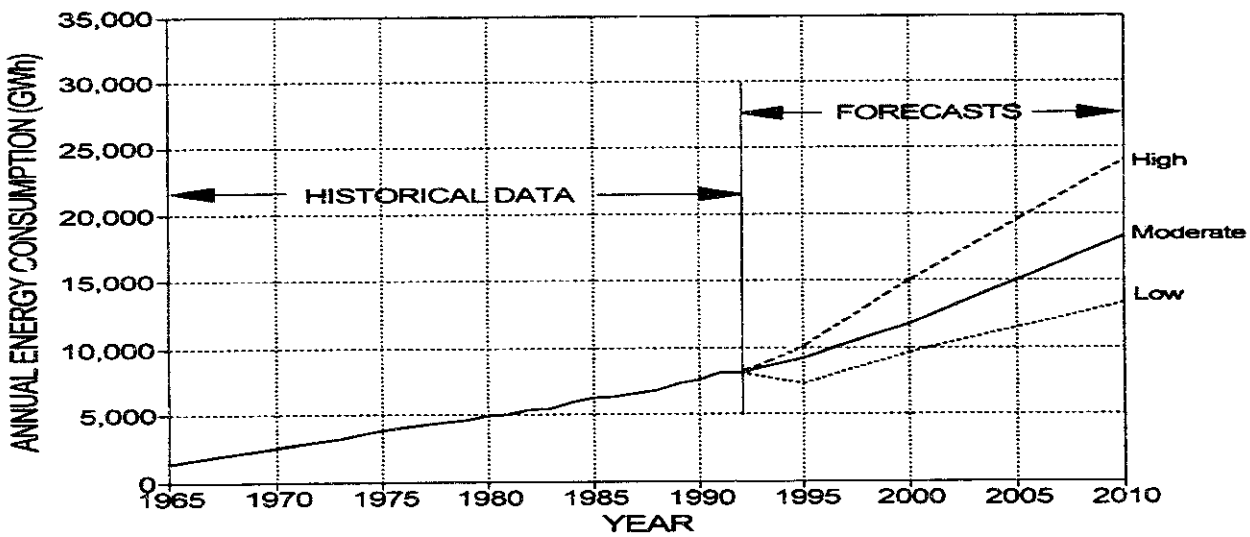

Figure 4: Historical and Projected Energy Consumption of Kyrgyzstan

Under the High Growth or official scenario, the demand would grow at an average annual growth rate of 8.0 percent for the period 1995-2000 and 4.8 percent for the period 2000-2010. Under the Moderate Growth scenario, the demand is expected to increase from 8,112 GWh in 1992 to 11,750 GWh in 2000 and to 18,350 GWh in 2010. This would be represented by an average annual growth rate of 4.7 percent for the period 1992-2000, and 4.6 percent for the period 2000-2010. For the Low Growth scenario, annual demand would decline by 9.8 percent until 1995 due to declining industrial consumption and slower residential demand growth, after which time an average growth rate of 4.1 percent would be assumed.

In addition to generating electricity to meet internal consumption, Kyrgyzstan has been a net exporter of electricity since 1978 involving seasonal exchange. Between 1988 and 1991, net exports averaged about 5,000 GWh per year, and have been reduced since then as a ramification of the new political and economic realities of the region.

Currently there are no long-term power sales agreements between the republics of Central Asia. However, assumptions of future exports were included in the official or High Growth scenario, with alternative export forecasts developed for the other two scenarios. There is a need, however, to clearly define the power market of Central Asia and the export potential from Kyrgyzstan as important considerations which are beyond the scope of this study.

For this study, net exports are expected to vary between 1,500 and 2,000 GWh until year 2000 and regain their 1988-91 level thereafter. Net exports are expected to vary between 4,500 GWh (Low Scenario) and 6,500 GWh (Moderate and High) in the year 2010. Historical data and projections for the internal demand of Kyrgyzstan combined with net exports are shown graphically in Figure 5.

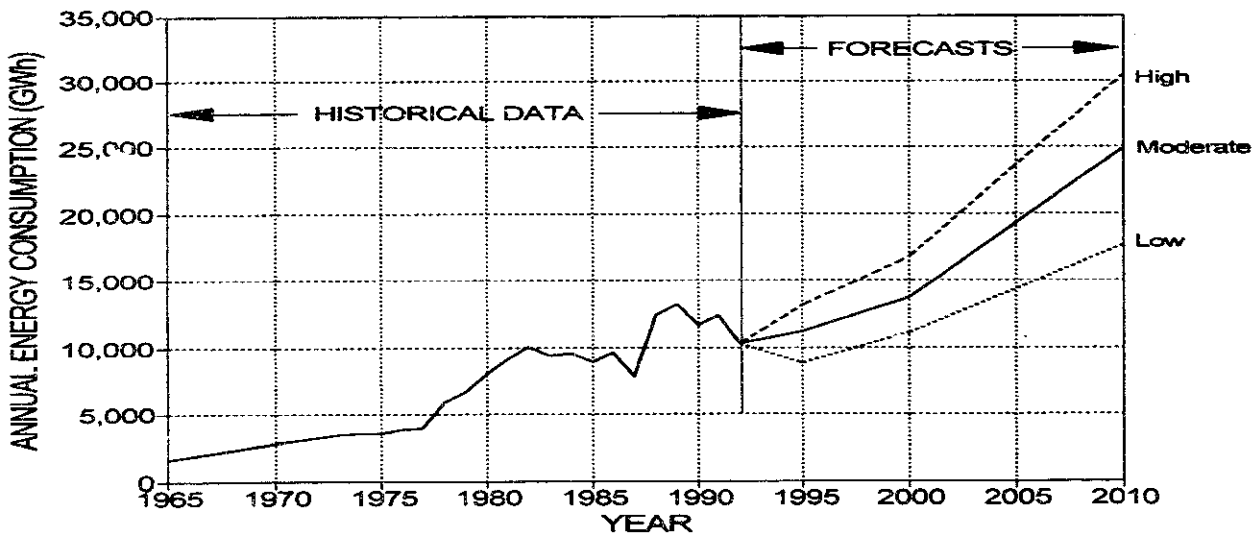

Figure 5: Historical and Projected Demand Including Net Exports

Kambarata, Kirov and Upper Naryn Hydroelectric Projects

Of the 26,000-MW hydroelectric potential of Kyrgyzstan only 2,740 MW have been developed to date, primarily on the lower Naryn river. The development of the Naryn river and its tributaries has been planned by the KSEC and the THDI. Preliminary, feasibility, and/or pre-design studies have been performed for many sites. For this study, KSEC selected to review the following sites for their economic attractiveness, stage of development (Kambarata), power addition to existing facilities (Kirov), and service for an isolated regional area and growing export market (Upper Naryn).[1] They are

- *Kambarata 1 and 2 projects - totaling 1,900 MW and 360 MW, respectively, and located in the middle part of the Naryn river between the Togoztural basin in the east and the Ketmentub basin in the west, just upstream of the reservoir formed by the existing Toktogul hydroelectric project.*

- *Kirov project - totaling 21 MW and located at the site of an existing dam and irrigation water storage reservoir on the Talas River in northwestern Kyrgyzstan.*

- *Upper Naryn projects - comprised of eight sites in the Upper Naryn basin and totaling 529.5 MW.*

Kambarata Projects

Kambarata 1. As proposed by THDI, the Kambarata 1 project consists of a 275-m-high dam built by controlled blasting, two combined power/spillway tunnels, four penstocks, a 4-unit powerhouse and an outdoor switchyard. The reservoir would have a live storage of about 3,430 million cubic meters and provide seasonal storage. The installed capacity of the plant will be 1,900 MW (maximum net head of 185 m with a total discharge of 1,150 m^3/s). The average energy production is 5,088 GWh/yr. Design head is 166.5 m and design unit discharge amounts to 270 m^3/s. A conventional dam alternative, consisting of a concrete double-curvature arch dam and 1,700 MW of installed capacity, which had also been analyzed by THDI, was reviewed for this study as well. New cost estimates were developed for both dams. The total construction cost is estimated to vary between $1.67 billion for the blast dam alternative and $1.85 billion for the arch dam alternative (March 1993 price level).

Kambarata 2. The Kambarata 2 Project is located just downstream of the Kambarata 1 Project and is about 30 percent complete. Although the construction started before Kambarata 1 was initiated, important project features were designed and built based on the

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[1] A number of additional sites, while possibly attractive, are located farther away from load centers or 500-kV transmission lines and were not subject to this evaluation. Other small hydro and mini-hydro projects were developed in the 1920's and 1930's and are presently abandoned; their rehabilitation may also be economically attractive, but again, were not part of this evaluation.

assumption that the Kambarata 1 dam would be in place by the time the downstream development was completed, or at least very soon after completion. The proposed project consists of a 62-m-high blast dam, a three-bay power intake and three parallel power tunnels, a spillway tunnel, a three-unit surface powerhouse and outdoor switchyard. The installed capacity of the plant will be 360 MW. The average energy production is estimated at 1,116 GWh. The design net head of the installation is 47.5 m and the unit design discharge amounts to 280 m^3/s. A conventional fill dam was also reviewed. The total construction cost to complete the project is estimated to vary from between $261 million (blast dam) and $281 million (fill dam).

An initial staged development was investigated that comprised only a two-unit installation instead of three units. Average annual energy generation would only be reduced by about 4 percent. This would, however, result in an initial investment reduction of about $30 million.

Kirov Project

The existing water storage reservoir of the proposed Kirov Hydroelectric Project has been operated since 1975 for seasonal regulation of water which is used from April to September for downstream irrigation. The reservoir provides seasonal storage for about 105,000 hectares (ha) which include 20,000 ha in Kyrgyzstan and 85,000 ha in Kazakhstan. The hydroelectric project would use the irrigation discharges to produce electric energy. Therefore, under current operating conditions, it would produce small amount of energy in the peak demand months in the winter, and large amount of energy in the summer. The project proposed by THDI consists of a power intake at the existing dam, a power tunnel through the right bank of the river, a surface penstock with a manifold trifurcation leading to a 3-unit powerhouse, a tailrace canal, and an outdoor switchyard. The installed capacity of the plant will be 21 MW (net design head of 41 m, 3-unit discharge of 59 m^3/s). The average energy production is estimated at 69.7 Gwh/yr. Total construction cost for the Kirov project is estimated at $ 19.4 million.

Upper Naryn Projects

The Upper Naryn hydroelectric potential was investigated by THDI in the late 1980's. Eight sites were inventoried (reconnaissance study level). One of them, the Naryn 1 Hydroelectric Plant, was developed at the feasibility level (Technical and Economic Analyses) in 1992. Table 1 presents the main characteristics of the eight powerplants, as defined by THDI.

Table 1

UPPER NARYN HYDROELECTRIC PROJECTS

Project Name	Project Type	Design Net Head (m)	Design Discharge (m^3/s)	Installed Capacity (MW)	Dependable Capacity (MW)	Annual Energy Production (GWh/yr)
Oruktam 1	RES	97	70	60	40	254
Oruktam 2	DIV	112	50	48	43	259
Echinaryn	DIV	22	50	9	8	50
Dzhanykel	RES	141	109	130	48	470
Akbulunsk	ROR	74	157	100	24	372
Naryn 1	DIV	45	157	62	14	227
Naryn 2	DIV	43	160	60	15	235
Naryn 3	DIV	50	160	60	17	254
TOTAL	n/a	n/a	n/a	529	n/a	2,121

Notations : RES = Reservoir storage project
ROR = Run of river
DIV = Diversion project (canal or tunnel)

Construction Cost Estimates

Extensive discussions were held with KSEC, THDI, and the Naryn Hydro Energy Construction Company (NHECC) which has been building all the Lower Naryn hydropower projects. The latest cost estimates prepared by THDI and prices available from the Ministry of Economics, which all reflect a March 1993 price level, were reviewed. These estimates and prices were converted into US dollars by using an exchange rate of 800 roubles per dollar. This conversion resulted in unit prices (US dollar per installed kilowatt) considerably below international price levels. New cost estimates were then developed to reflect current and future market conditions and international bidding.

New estimates were developed for labor costs, materials costs and construction equipment rates. Labor is expected to be of national origin. An experienced construction work force is available from the NHECC for future projects. The origin of materials and equipment was considered, either from the national market or imported from Russia or other countries. In addition, an analysis of construction costs of hydropower projects in India, Pakistan and

China was performed to serve as an additional basis for cost estimates in Kyrgyzstan. Current prices were modified to reflect rapid changes in the price structure of imported fuels, material, and equipment. Construction cost estimates were derived based on quantities developed by the THDI and Harza. The costs are summarized in Table 2, and they reflect a March 1993 price level.

Table 2

CONSTRUCTION COST ESTIMATES

Project Name	Installed Capacity (MW)	Average Annual Energy (GWh)	Construction Cost Total ($x10^6)	Construction Cost Unit Cost ($/kW)
Kambarata 1				
Controlled Blast Dam	1,900	5,088	1,675	882
Arch Dam	1,700	4,611	1,850	1,088
Kambarata 2				
2-unit	240	1,072	231	961
3-unit	360	1,116	261	724
Kirov	21	70	19	925
Oruktam 1	60	254	180	3,000
Oruktam 2	48	259	180	3,750
Echinaryn	10	50	37	3,750
Dzhanykel	130	470	176	1,358
Akbulunsk	100	372	135	1,350
Naryn 1	62	227	97	1,562
Naryn 2	60	235	100	1,667
Naryn 3	60	254	115	1,917

Reservoir Operation Studies

The primary purpose and the current practice of the Toktogul reservoir has been to provide multi-year and seasonal storage for irrigation demand in Uzbekistan and Kazakhstan. Water is stored behind the Toktogul reservoir for summer releases to meet this demand. The projects downstream of Toktogul do not have seasonal storage and are used for daily peaking and regulation. Power and energy is generated as the by-product of irrigation releases. As a result, electricity generation in the summer months is in excess of the internal demand of Kyrgyzstan. Within the former Soviet Union, this excess was transmitted to the other republics of Central Asia through the 500-kV transmission network (see Figure 3). In winter, when water was conserved for the summer irrigation requirements, power would flow back from the other Central Asian republics into Kyrgyzstan to meet the winter load of Kyrgyzstan. A regional balance and optimization of water for power and irrigation was achieved.

Reservoir operation studies performed by THDI, based on these past irrigation priorities, were therefore reviewed, and then a series of alternative reservoir operation studies were performed to evaluate the operation of these projects as primarily power projects with a constant minimum release of only 100 m^3/s for downstream requirements. This was done to evaluate the output of existing and future projects if they were to meet the electrical power demand of Kyrgyzstan as a first priority. Figure 6 graphically shows the results of monthly dependable energy generation from the existing projects and the addition of Kambarata 1 and 2 under both modes of operation: irrigation and power scenarios. Under the power scenario, energy output from the hydro facilities would closely follow the monthly fluctuations of the internal demand of Kyrgyzstan (as shown on Figure 2 for year 1992) and would meet that demand without any power shortages during the winter months.

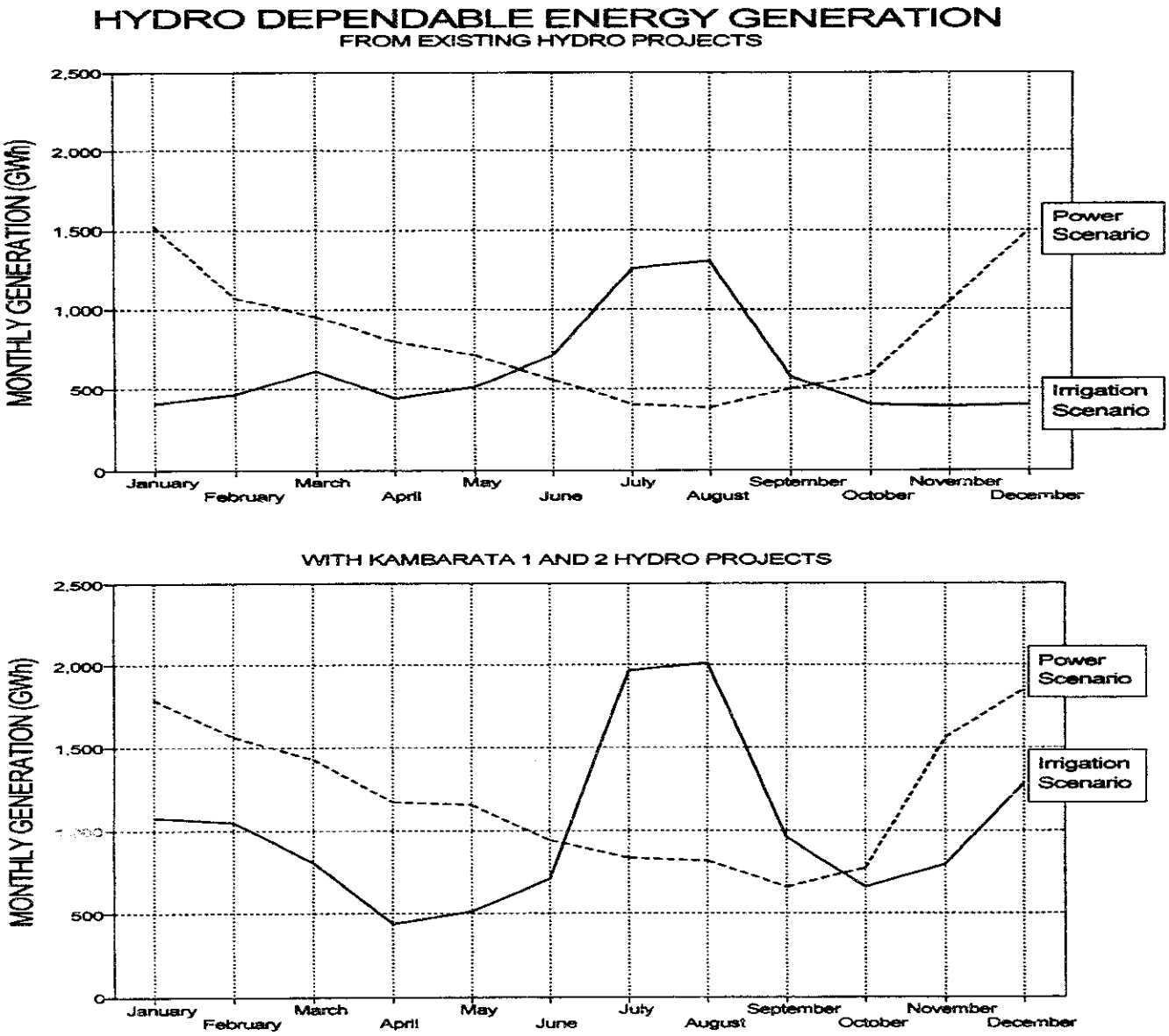

Figure 6: Monthly Hydropower Energy Generation

Economic Evaluation

An economic analysis was conducted to evaluate the economic feasibility of the proposed hydroelectric projects by comparing them to the most likely thermal alternatives: coal-fired, combined cycle gas turbine, or gas turbine powerplants depending on the size and operating mode of the hydropower project. Table 3 presents input data specific to the thermal alternatives. Two sets of assumptions are presented to reflect the differences in size and location the hydropower projects. These assumptions are based on international construction costs of thermal plants and fuel prices. Similar assumptions were made for the development of the hydro construction costs. These construction and operating costs are also representative of thermal costs of new facilities in Uzbekistan and Kazakhstan. Projects economically attractive for Kyrgyzstan would show a similar economic rate of return for Uzbekistan and Kazakhstan. A 12 percent real discount rate and no escalation or inflation were used in the economic analysis.

Table 3

ECONOMIC ANALYSIS - INPUT DATA FOR THERMAL GENERATION

	Large Projects		Small Projects	
	Coal-Fired	CCGT	Coal-Fired	GT
Construction Cost ($/kW)	1,300	750	1,600	500
Fixed O&M Cost ($/kW/year)	25	15	30	25
Variable O&M Cost ($/MWh)	2.5	3.5	3.0	5.0
Type of Fuel	Coal	Gas	Coal	Gas
Price of Fuel ($/MBtu)	2.0	4.0	2.5	5.0
Energy Value ($/MWh)	20	30	25	60
Construction Period	4	2	4	1

Table 4 summarizes the results of the economic analysis. The Kambarata 2 project was analyzed under two modes of development. The first mode of development assumes an initial phase with two units and an installed capacity of 240 MW due to the potential postponement of the upstream Kambarata 1 storage project. The second mode of development assumes that the Kambarata 1 project will be built shortly thereafter and the Kambarata 2 project has three units with an installed capacity of 360 MW. The Kambarata 2 project shows an attractive benefit-cost (B/C) ratio under both alternatives: 1.26 and 1.68, respectively, using a 12 percent discount rate. The corresponding equalizing discount rates (rate of return) are 16.3 and 26.2 percent, respectively.

The Kambarata 1 project is also economically attractive with a B/C ratio of 1.25 and an equalizing discount rate of 15.9 percent for the controlled blast dam alternative, and a B/C ratio of 1.09 and an equalizing discount rate of 13.4 percent for the arch dam alternative. The Kambarata 1 project would also provide additional firm and secondary power and

energy benefits to the Kambarata 2 project, which would further increase the economic attractiveness of the project.

The Kirov project is marginally attractive with a B/C ratio of 0.96 and an equalizing discount rate of 11.3 percent. The Upper Naryn projects have B/C ratios varying between 0.74 and 1.20. Construction costs of these projects should be refined and a more detailed analysis of alternative thermal generation costs to provide electricity in the areas surrounding these hydropower projects should be performed.

Table 4

RESULTS OF THE ECONOMIC ANALYSIS

Project Name	Benefit-Cost Ratio	Equalizing Discount Rate (%)
Kambarata 2		
2-unit	1.26	16.3
3-unit	1.68	26.2
Kambarata 1		
Controlled Blast Dam	1.25	15.9
Arch Dam	1.09	13.4
Kirov	0.96	11.3
Oruktam 1	0.75	7.3
Oruktam 2	0.80	8.1
Echinaryn	0.74	7.1
Dzhanykel	1.11	14.0
Akbulunsk	1.20	15.2
Naryn 1	1.03	12.5
Naryn 2	1.04	12.5
Naryn 3	0.98	11.7

Hydro Expansion Program

Figure 7 shows the demand and supply under the Moderate- and Low-growth scenarios with and without net exports. In addition to the existing thermal and hydro facilities, only the Kambarata 1 and 2 projects have been added. For the existing thermal facilities, it was assumed that their generation output would be associated with district heating requirements and would not increase over time. The corresponding annual thermal energy generation is expected to be about 3,950 GWh. Since hydropower generation varies depending upon the amount of runoff available, both the firm (or dependable) and average hydro energy generation are presented in Figure 7. It was assumed that the excess hydro energy generated during the summer would be exported to surrounding republics and compensated

by thermal imports in the winter. Hydro energy presented in Figure 7 corresponds to total average annual energy that can be produced by the projects.

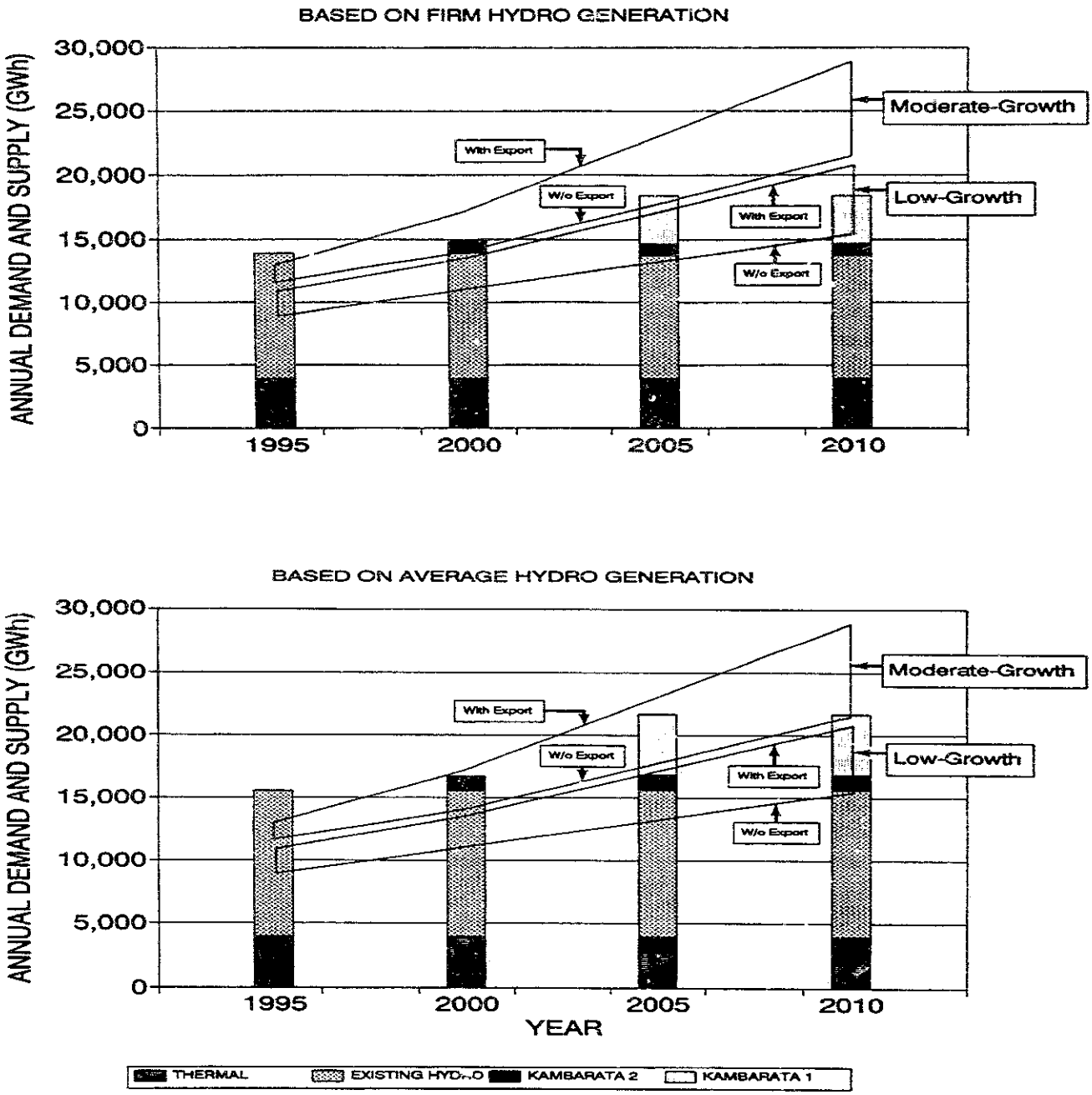

Figure 7: Demand and Supply

Perusal of Figure 7 reveals that, under the Moderate-growth scenario, additional generation would be required by the end of the 1990's if Kyrgyzstan wants to continue meeting their

export market and even their own internal demand under drought conditions. Then, depending on the assumptions made on future demand within Kyrgyzstan and the amount of energy that can be exported from Kyrgyzstan, the Kambarata 1 project would need to be in operation sometime during the next decade.

Conclusion

Future electricity demand outlook, trade (exports) incentives, and operational benefits relative to costs indicate that the construction of the Kambarata 1 and 2 hydropower projects should be pursued as a top priority of the Government of Kyrgyzstan. The Kambarata 2 project is already under construction and major works such as power tunnels are well underway. About 30 percent of the construction is complete (see Figure 8 which shows a photograph of the power tunnel outlets and powerhouse foundation excavation), but a current lack of funding has brought construction activities to a halt. The European Bank for Reconstruction and Development (EBRD) has performed a parallel study on this project and is already looking into financing options to complete the Kambarata 2 project. At the same time, preparation of technical and financial documents required for financing the implementation of the Kambarata 1 project should continue.

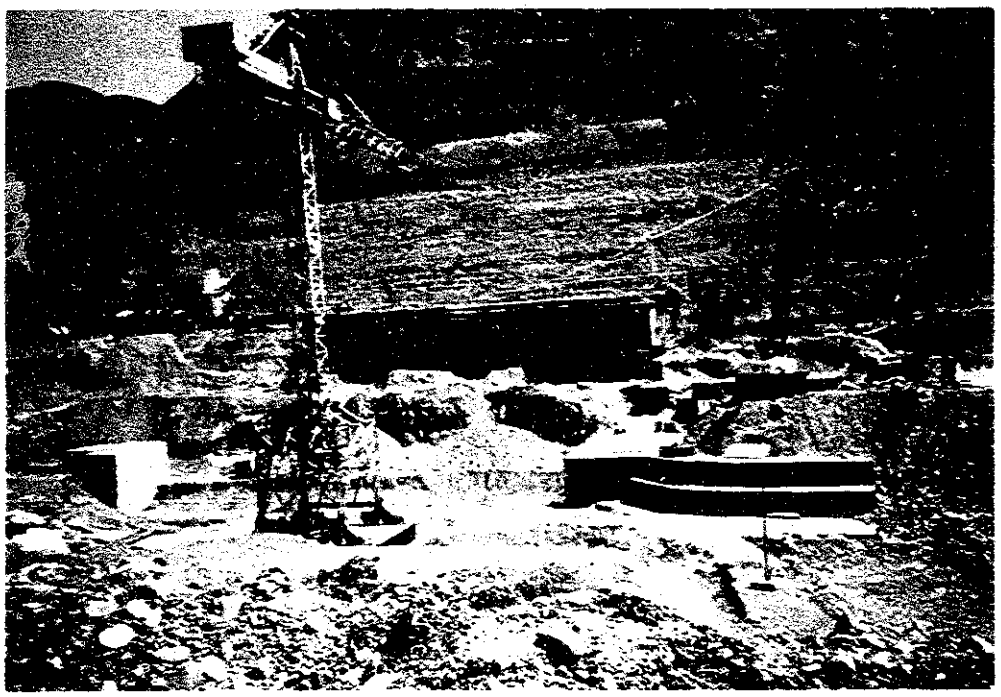

Figure 8: Construction Site of Kambarata 2 Project

The export of hydro electricity from Kyrgyzstan to Uzbekistan and Kazakhstan should also be considered into the overall energy balance of payments for Kyrgyzstan. Kyrgyzstan has severe energy deficits and imports coal, oil and gas from both Uzbekistan and Kazakhstan.

At the same time, these two countries have vested interests in the operation of the Toktogul reservoir to maintain adequate storage for summer irrigation releases, specially during drought years. Development of the Kambarata projects would provide a major increase of hydropower generation in the winter months while maintaining water storage in the Toktogul reservoir for irrigation purposes. A strong cooperation between these countries and international lending agencies would make the implementation of the Kambarata projects very attractive, both for power and irrigation benefits.

Recommendations for Further Action

Further activities are recommended:

Kambarata Projects

(1) The Government of Kyrgyzstan should declare that the completion of the Kambarata 2 project is a top funding priority.

(2) The design of the Kambarata 2 project should be refined for an initial 240 MW development with provision to add a third 120 MW unit.

(3) All necessary technical and financing-related information should be compiled for the preparation of tender documents for civil works and equipment supply and Banks' approval of construction financing for the Kambarata 2 project.

(4) The configuration of the dam for the Kambarata 1 project should be finalized through a comparison of the proposed controlled blasting techniques to a more conventional design such as concrete arch dam. Staging development and ways to reduce initial investment should also be considered.

(5) Contacts should be made with neighboring countries to discuss their potential participation in the development of the Kambarata projects.

General Hydropower-Sector Activities

(1) Existing contractual agreements between the Central Asian republics regarding the use and operation of the Toktogul reservoir and other uses of the Naryn and Syrdaya rivers for irrigation and power should be reviewed. Long-term operating criteria for the Toktogul project should be developed that are acceptable to all parties, and benefits and costs should be established.

(2) The electricity export potential to the neighboring republics and other countries nearby should be delineated, and legal and contractual documents related to short-

and long-term power exchanges between Kyrgyzstan and the various Central Asian republics should be negotiated.

(3) Sources of international and local financing should be secured, and an appropriate legal and institutional structure (e.g., a joint-stock corporation) should be established to develop hydroelectric projects.

(4) The need for rehabilitation/upgrade and expansion of the transmission/distribution network of Kyrgyzstan to meet increased level of electrification, residential electric heating demand, and export should be planned. Tender documents for equipment supply should be prepared.

(5) The need for improvements in telecommunications and controls between the dispatch centers of Kyrgyzstan and other Central Asia republics should be assessed.