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JOINT ENERGY ALTERNATIVES STUDY

Hydroelectric Power Generation Assessment for Russia

DRAFT-Final Report

Prepared for

Burns and Roe Company

by

Harza Engineering Company
and
Energopromtechnika Group, Ltd

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Foreword

Harza Engineering Company and The Energopromtechnika Group Ltd have prepared this report as part of the Joint (Russian-American) Energy Alternatives Study for the Russian Federation The objective of this report is to identify priority projects for foreign investment which would economically increase the electricity generation capacity of Russia through hydroelectric power

The majority of the data presented in this report were developed by the Russian "Gidroproject" Hydroproject Design Institute of Moscow (under subcontract to Energoprom) who have traditionally been responsible for the design and construction of hydroelectric plants in the former Soviet Union and now the Russian Federation The data has been reviewed and assembled into this report by Harza and Energoprom

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Hydroelectric Power Generation Assessment for Russia

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List of Abbreviations

JSC	Joint Stock Company
kWh	kilowatt-hour
kW	kilowatt 10^3
MW	Megawatt 10^6
GW	Gigawatt 10^9
US$	United States Dollar
Rb	Russian Federation Ruble
m	meter
m^3	Cubic Meter
km	kilometer
IRR	Internal Rate of Return
UESS	Unified Energy System of Siberia
EES	European Energy System
ODD	Open Distribution Devices (Transmission Lines)
FEUES	Far East Unified Energy System

Chapter 1 EXECUTIVE SUMMARY

This report presents the results of a hydroelectric power generation assessment for the Russian Federation The joint American and Russian Project Team of Harza Engineering Company (Chicago) and Energopromtechnika Group (Moscow) have prepared this report under contract with Burns & Roe Company (Washington, DC)

1 1 Objective

The objective of the current study is to identify financial investment requirements to maintain and expand the hydroelectric aspect of the Russian electric generation system to meet the objective of the Joint (Russian-American) Energy Alternatives Study (JEAS) which is to economically increase the generation capacity of the Russian Federation

1 2 Methodology

The Project Team has prepared an inventory of the existing hydroelectric plants in the Russian Federation and we have identified priority projects for foreign investment For this study, the Project Team looked at four different categories to identify potential plants for investment to increase the electric generation capacity The four categories of investigation were

a Existing Plants, completion of ongoing rehabilitation reconstruction
b Existing Plants new rehabilitation/expansion reconstruction
c New Plants, completion of ongoing construction
d New Plants, start construction of planned plants

The goal of the Project Team was to identify plants with the highest return in electric generation capacity for the least investment

1 3 Results

The Project Team has identified a total of 16 priority plants with a total generation capacity of 13 744 MW and energy output of 55 365 kWh for an investment of $5 79 billion (1991) over the period 1995 to 2001

> Note that all costs presented herein are "overnight" construction costs estimated by the Russian counterpart excluding any financing, inflation or escalation The costs are presented in 1991 United States Dollars at a time when one dollar was approximately equal to one Russian Rouble

Table 1 1 presents a summary of the Project Characteristics and **Table 1 2** presents a summary Investment Plan

The proposed investment plan will provide a 50-year design life extension for seven existing plants which account for 5737 4 MW and 24 05 billion kWh of energy production The existing plants would probably be out of service by 2000 without rehabilitation

The proposed investment provides 7206 7 MW and 30 515 billion kWh of new energy over the next 7 years Several new plants currently under construction have been identified as priority projects due to the low incremental cost of new power since much of the initial mobilization and infrastructure improvements have already been sunk over a period of years by the government and current plant owners

The Project Team has identified several new plants currently under design for priority investment to start construction based on low investment costs minimal environmental impacts and the regional need for power In the case of two of the three plants, the new plants would be built on existing sites which had been abandoned due to run-down equipment and high operating costs These problems can be removed with independent investment for new mechanical and electrical equipment, and new controls The third new plant is actually a staged expansion of an existing plant utilizing the construction assets already in place

Table 1 1 - Summary of Investment Requirements Characteristics

Project Type	Number of Plants	Capacity (MW)		Output (billions of kWh)		Investment $billion (1991)
		Existing	New	Existing	New	
Existing Plants FINISH Reconstruction	3	4 891	5 106	21 260	23 920	0 525
Existing Plants START Reconstruction	4	846 4	954	2 790	2 891	0 405
New Plants FINISH Construction	6	800	6861	0 800	27 694	4 240
New Plants START Construction	3	0	823 1	0	0 860	0 620
Totals	16	6537 4	13744 1	24 85	55 365	5 790

Table 1 2 - Summary of Investment Requirements
Investment Plan

Plant Type	Investment Requirement Billion $ (1991 US$=1Rb)							
	1995	1996	1997	1998	1999	2000	2001	Total
Existing Plant, Finish Reconstruction								
Cash Flow %	15%	21%	30%	19%	15%	--	-	100%
Investment billion US$	0800	1125	1575	1000	0750			5250
Plant Capacity MW	4891	4947	5002	5054	5106	5106	5106	5106
Existing Plant, Start Reconstruction								
Cash Flow %	16%	30%	31%	14%	9%	-	-	100%
Investment billion US$	066	1215	1245	057	036			405
Plant Capacity MW	846	883	920	942	954	954	954	954
New Plants, Finish Construction								
Cash Flow %	10%	17%	17%	16%	14%	13%	13%	100%
Investment billion US$	4443	7289	732	6711	5837	540	540	4 240
Plant Capacity MW	800	1000	1374	2653	4553	6227	6861	6861
New Plants, Start Construction								
Cash Flow %	11%	17%	16%	14%	14%	14%	14%	100%
Investment billion US$	067	1105	1005	0855	0855	0855	0855	0 620
Plant Capacity MW	0	0	23 1	223 1	423 1	623 1	823 1	823 1
TOTALS								
Cash Flow %	11%	18%	19%	16%	13%	11%	11%	100%
Investment billion US$	6573	1 0734	1 1145	0 9136	7802	6255	6255	5 790
Plant Capacity MW	6537	6830	7319	8872	11036	12910	13744	13744

1 4 Existing Plants Currently Under Rehabilitation Reconstruction

The Project Team has identified three priority hydroelectric plants which are currently undergoing rehabilitation for financial investment to complete construction in an expedited manner The characteristics of these three plants - Nizhne-Tulomskaya Volzhskaya (named after V I Lenin) and Volzhskaya (named after XXII Congress) - are shown on **Table 1 3** These plants require an investment of approximately $525 million over the five year period 1995 to 1999 as shown on **Table 1 4**

1 5 Existing Plants to Start Rehabilitation Reconstruction

The Project Team has identified a total of twenty-five hydroelectric plants requiring rehabilitation prior to 2010 Without rehabilitation these plants will likely have to be taken out of service by the year 2010 The Project Team has identified four plants for priority investment based on their current condition The characteristics of these four plants - Kamskaya, Volkhovskaya, Pavlovskaya, and Uglitchskaya - are shown on **Table 1 5** Without rehabilitation the four priority plants will likely be out of service by the year 2000 The estimated investment requirement for rehabilitation of the four priority plants is $405 million (1991) over the five year period 1995-1999 as shown on **Table 1 6**

Rehabilitation of the selected priority plants will guarantee the supply of energy from these plants by extending their service lives

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Table 1 3 - Priority Projects to Continue Rehabilitation/Expansion Construction Characteristics

Existing Plant	Region	Generation Capacity (MW)		Avg Annual Energy (billion kWh)	
		Before Rehab	After Rehab	Before Rehab	After Rehab
Nizhne-Tulomskaya	Northwest	50	57	0 28	0 31
Volzhskaya (named after Lenin)	Middle Volga	2 300	2 400	9 30	10 9
Volzhskaya (after XXII Congress)	Center	2 541	2 649	10 52	11 1
TOTALS		4 891	5 106	21 26	23 92

Table 1 4 - Priority Projects to Continue Rehabilitation/Expansion Construction Investment Plan

Existing Plant	Investment Requirement Billion $ (1991 US$=1Rb)					
	1995	1996	1997	1998	1999	Total
Nizhne-Tulomskaya						
Cash Flow %	20%	50%	30%			100%
Investment billion US$	0050	0125	0075			0250
Plant Capacity MW	50	54	57	57	57	57
Volzhskaya (named after Lenin)						
Cash Flow %	15%	20%	30%	20%	15%	100%
Investment billion US$	0375	0500	0750	0500	0375	2500
Plant Capacity MW	2300	2325	2350	2375	2400	2400
Volzhskaya (after XXII Congress)						
Cash Flow %	15%	20%	30%	20%	15%	100%
Investment billion US$	0375	0500	0750	0500	0375	2500
Plant Capacity MW	2541	2568	2595	2622	2649	2649
TOTALS						
Cash Flow %	15%	21%	30%	19%	15%	100%
Investment billion US$	0 0800	0 1125	0 1575	0 1000	0 0750	5250
Plant Capacity MW	4891	4947	5002	5054	5106	5106

Table 1 5 - Priority Projects to Start Rehabilitation/Expansion Characteristics

Plant Name	Region	Capacity (MW)		Output (billion kWh)	
		Before Rehab	After Rehab	Before Rehab	After Rehab
Kamskava	Urals	504	552	1 760	1 800
Volkhovskava	Northwest	66	96	0 360	0 410
Pavlovskava	Urals	166 4	180	0 500	0 503
Uglitchskaya	Center	110	126	0 170	0 178
TOTALS		846 4	954	2 790	2 891

Table 1 6 - Priority Projects to Start Rehabilitation/Expansion Investment Plan

Plant Name		Investment Requirement Billion $ (1991 US$=1Rb)					
		1995	1996	1997	1998	1999	Total
Kamskaya	Cash Flow %	15%	20%	30%	20%	15%	100%
	Cash Flow billion US$	036	048	072	048	036	240
	Plant Capacity MW	504	516	528	540	552	552
Volkhovskava	Cash Flow %	15%	35%	35%	15%		100%
	Cash Flow billion US$	009	021	021	009		060
	Plant Capacity MW	66	76	86	96	96	96
Pavlovskaya	Cash Flow %	20%	50%	30%			100%
	Cash Flow billion US$	004	010	006			020
	Plant Capacity MW	166	173	180	180	180	180
Uglitchskava	Cash Flow %	20%	50%	30%			100%
	Cash Flow billion US$	017	0425	0255			085
	Plant Capacity MW	110	118	126	126	126	126
TOTALS	Cash Flow %	16%	30%	31%	14%	9%	100%
	Cash Flow billion US$	066	1215	1245	057	036	405
	Plant Capacity MW	846	883	920	942	954	954

1 6 New Plants Currently Under Construction

The Project Team has identified six priority new hydroelectric plants which are currently under construction for financial investment to complete construction in an expedited manner The characteristics of these six plants - Aushigerskaya, Zelentchukskaya, Zaramagskaya Zagorskaya-1, Bogutchanskaya and Bureyskaya - are shown on **Table 1 7** These plants require an investment of approximately $4 24 billion (1991) over the seven year period 1995 to 2001 as shown on **Table 1 8** These project will add 6 861 MW and 27 694 billion kWh of energy when completed In aggregate these projects will cost approximately $618/kW of generation capacity and $0 15 /kWh of energy produced

1 7 New Plants to Start Construction

The Project Team has identified three new hydroelectric plants for financial investment to start construction The characteristics of these three plants - Zagorskaya-2 Ziuratkulskaya, and Pravdinskaya - are shown on **Table 1 9** These plants require an investment of approximately $620 million (1991) over the seven year period 1995 to 2001 as shown in **Table 1 10**

Zagorskaya-2 is an expansion of Zagorskaya-1 Pumped-storage plant located near Moscow The other two projects are a revitalization of plants which had been abandoned previously because of poor equipment condition and efficiency and the cost of replacement Revitalizing abandoned plants with new equipment and controls minimizes the environmental concerns and reduces the overall construction costs The civil structures at both plant locations are reported to be in good condition

Table 1 7 - Priority New Plants to Finish Ongoing Construction Characteristics

Plant Name	Region	Capacity (MW)		Output (Billion kW-hr)	
		Before Rehab	After Rehab	Before Rehab	After Rehab
Aushigerskava	North Caucasus	0	57	0	0 236
Zelentchukskava	North Caucasus	0	262	0	0 769
Zaramagskava	North Caucasus	0	342	0	0 789
Zagorskava PS 1	Center	800	1200	0 800	1 200
Bogutchanskava	Siberia	0	3000	0	17 6
Bureyskaya	Far East	0	2000	0	7 1
TOTALS		800	6861	0 800	27 694

Table 1 8 - Priority New Plants to Finish Ongoing Construction Investment Plan

Plant Name	Investment Requirement Billion $ (1991 US$=1Rb)							
	1995	1996	1997	1998	1999	2000	2001	Total
Aushigerskaya								
Cash Flow %	20%	50%	30%	--	--	-	-	100%
Cash Flow billion US$	0206	0515	0309					0 103
Plant Capacity MW	0	0	57	57	57	57	57	57
Zelentchukskaya								
Cash Flow %	10%	20%	30%	30%	10%		--	100%
Cash Flow billion US$	0204	0408	0612	0612	0204			0 204
Plant Capacity MW	0	0	60	160	262	262	262	262
Zaramagskaya								
Cash Flow %	10%	20%	30%	30%	10%		-	100%
Cash Flow billion US$	0233	0466	0699	0699	0233			0 233
Plant Capacity MW	0	0	57	228	342	342	342	342
Zagorskaya PS - 1								
Cash Flow %	20%	50%	30%	-			--	100%
Cash Flow billion US$	020	050	030					100
Plant Capacity MW	800	1000	1200	1200	1200	1200	1200	1200
Bogutchanskaya								
Cash Flow %	10%	15%	15%	15%	15%	15%	15%	100%
Cash Flow billion US$	140	210	210	210	210	210	210	1 400
Plant Capacity MW	0	0	0	666	1666	2666	3000	3000
Bureyskaya								
Cash Flow %	10%	15%	15%	15%	15%	15%	15%	100%
Cash Flow billion US$	220	330	330	330	330	330	330	2 200
Plant Capacity MW	0	0	0	342	1026	1700	2000	2000
TOTALS								
Cash Flow %	10%	17%	17%	16%	14%	13%	13%	100%
Cash Flow billion US$	4443	7289	732	6711	5837	540	540	4 240
Plant Capacity MW	800	1000	1374	2653	4553	6227	6861	6861

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Table 1 9 - Priority New Plants to Start Construction Characteristics

Plant Name	Region	Capacity (MW)		Output (Billion kW-hr)	
		Before Rehab	After Rehab	Before Rehab	After Rehab
Zagorskaya PS 2	Center	0	800	0	800
Ziuratkulskaya	Urals	0	10 4	0	030
Pravdinskaya	Northwest	0	12 7	0	030
TOTALS		0	823 1	0	860

Table 1 10 - Priority New Plants to Start Construction Investment Plan

Plant Name	Investment Requirement Billion $ (1991 US$=1Rb)							
	1995	1996	1997	1998	1999	2000	2001	Total
Zagorskaya PS - 2								
Cash Flow %	10%	15%	15%	15%	15%	15%	15%	100%
Cash Flow billion US$	057	0855	0855	0855	0855	0855	0855	0 570
Plant Capacity MW	0	0	0	200	400	600	800	800
Ziuratkulskaya								
Cash Flow %	20%	50%	30%	-	--	--	-	100%
Cash Flow billion US$	0030	0075	0045					0 015
Plant Capacity MW	0	0	10 4	10 4	10 4	10 4	10 4	10 4
Pravdinskaya								
Cash Flow %	20%	50%	30%	--	--	--	-	100%
Cash Flow billion US$	007	0175	0105					0 035
Plant Capacity MW	0	0	12 7	12 7	12 7	12 7	12 7	12 7
TOTALS								
Cash Flow %	11%	17%	16%	14%	14%	14%	14%	100%
Cash Flow billion US$	067	1105	1005	0855	0855	0855	0855	0 620
Plant Capacity MW	0	0	23 1	223 1	423 1	623 1	823 1	823 1

Chapter 2 INTRODUCTION

2 1 Terms of Reference

In September 1993, Russian Federation Prime Minister Chernomyrdin and United States Vice President Gore agreed on a joint effort to examine options for Russia's energy future The objective of the study is to develop a long-term comprehensive program for the Russian power sector The Terms of Reference [1] for this study state that

> "The Russian electric power sector will require major investments over the coming decades The sector's main problems include the high proportion of thermal generating plants which are currently beyond their planned operational life spans, doubts about the safety of older nuclear plants, and highly inefficient patterns of electricity use In the present state of the Russian economy, federal budget financing of power sector development has all but ended while new financing mechanisms appropriate to a market economy have not yet developed
>
> The international community, including the leaders of the G-7 group, attaches great importance to joint efforts in helping to solve these problems Fundamental conditions of investment in this most important sector of the Russian economy should be identified on a priority basis "

2 2 Hydropower Generation Assessment Objective

Hydroelectric energy is a significant component of the energy sector of the Russian Federation, representing 170 TWh/year or 17 percent of the total electric energy output of the country The economic potential of hydroelectric power has been estimated at 850 TWh/year, which indicates that substantial opportunity exists to increase current hydroelectric capacity and energy production

The objective of the current hydropower generation assessment is to prepare a time-phased

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investment plan for the period 1995 to 2000 for expansion of the existing hydroelectric energy production through

a rehabilitation/modernization of existing plants
b expansion of existing plants
c completion of partially-constructed plants
d construction of planned plants

Improvements in the transmission interties between Russia's regional power systems could also significantly strengthen the ability of the power sector to meet uncertain future power and energy demands

2 3 Scope of Current Study

The scope of services for the current study were identified in Harza's proposal to Burns & Roe dated 11-Mar-94 which was later informally revised to concentrate on mechanical and electrical equipment assessments to the exclusion of assessing the future needs of project civil works The following methodology has been established to meet the project objective

a Assess the condition of existing hydropower plants in European Russia (the region west of the Ural Mountains), and identify the plants requiring mechanical or electrical equipment rehabilitation and upgrading, assess current Russian plans for rehabilitation and upgrading, and establish recommended priorities for those plants requiring only mechanical and electrical facilities

b Identify and screen plants by region which are currently under construction assess current Russian plans for completion and establish priority projects

c Develop order of magnitude costs, time schedules, and capacity and energy production estimates for those projects in the higher priority categories

d Analyze operation of the hydropower stations in the Siberian Region which are scheduled to supply power to load centers in European Russia via new or upgraded transmission lines e Prepare a preliminary time-phased investment program for the period 1995-2000 which recommends the order and timing to implement the priority projects so as to increase hydroelectric energy production at a relatively low cost or with high return

This report represents the final deliverable product of the hydroelectric generation assessment study This report includes a preliminary investment program for hydroelectric generation in accordance with the stated project objectives

2 4 Implementation

The project work plan included the eight tasks divided into three stages as follows

<u>STAGE 1</u>

Task 1	Form Joint Russian-American Hydro Study Team
Task 2	Collect and Review Data

<u>STAGE 2</u>

Task 3	Assess Rehabilitation, Upgrade and Modernization Potential
Task 4	Assess Needs of Hydro Plants that Require Addition of Electrical & Mechanical Equipment
Task 5	Evaluate Available Siberian Hydroelectric Energy

<u>STAGE 3</u>

Task 6	Develop a Hydro Investment Program
Task 7	Prepare Results and Reports
Task 8	Review Draft-Final JEAS Report

Chapter 3 INVENTORY OF EXISTING HYDRO SYSTEM

3 1 Objectives

This chapter presents an inventory of hydroelectric plants greater than 30 MW in the Russian Federation as of 01-January-94 This data has been collected for two reasons First, an inventory of all existing projects was necessary to provide a database of information for selection of plants needing rehabilitation The JEAS-Working Group 5 also needed this data for their model of the Russian electric generating system

3 2 General Characteristics of Russian Hydroelectric Production

The power industry of the Russian Federation has developed from the plans initiated by V I Lenin which were started in 1920 The plan for the electrification of Russia was the earliest initiative to build a country's economy and industry on such a large scale The development of hydroelectric energy played a key role in the early development of Russia's energy system In 1994, hydropower accounts for approximately 42 9 GW of Russia's total installed capacity of 177 8 GW, or about 24 percent of the Unified Electric Power System (UEPS)

3 3 Inventory of Existing Plants

The Russian UEPS is divided into seven regions Basic plant data has been collected for 64 existing hydroelectric plants as shown on the **Table 3 1**

4 SEASONAL CAPACITY

RR Plants The seasonal capacity has been computed as (Nameplate Capacity)*(Seasonal Capacity Factor)*(Annual Capacity Factor) The seasonal capacity indicates the average indicated capacity available continuously on a non-dispatchable basis for the season The winter (Oct-Mar) season should be used for the purposes of reserve margin calculation

PH Plants The seasonal capacity has been computed as 90%*(Nameplate Capacity) based on U S experience for pondage hydro plants These values indicate the average capacity which the plant could be dispatched subject to the constraint of seasonal capacity factors The winter (Oct-Mar) season should be used for the purposes of reserve margin calculation

NOTE This information may be updated at a later point in time

5 CAPACITY FACTOR The 'Annual capacity factor has been computed from data supplied by our Russian counterpart as

CF=(Avg Multiyear Output kWh)/[(Nameplate Capacity)*8760 hours/yr)]

Seasonal Capacity Factors are the percentage (totalling for 2 seasons) of energy historically produced in that season as provided by our Russian counterpart Data shown in [brackets] was not given therefore Harza has estimated these values based on other projects on the same river or in the same vicinity and our experience The amount of send-out generation (SOG) which could be produced during the period can be computed as follows

Annual SOG = [Annual Capacity Factor] * [Total Plant Capacity] * 8760 hours/year

Winter (Oct-Mar) SOG = [Winter Capacity Factor] * [Total Plant Capacity] * 4380 hours/year

Summer (Apr-Sep) SOG = [Summer Capacity Factor] * [Total Plant Capacity] * 4380 hours/year

NOTE This information may be updated at a later point in time

6 O&M (operation and maintenance) COSTS (1991 US$) No O&M cost data has been supplied by our Russian counterpart Therefore, Harza has estimated these values based on U S hydroplant O&M costs (' Electric Plant Cost and Power Production Expenses 1991) based on the following

Fixed Cost U S average in 1991 was $2 89/MWh less than 5% of this cost is attributable to labor so no adjustment has been made for the Russian market For each project Fixed O&M costs were estimated as $2 89/MWh*(Avg Multiyear Output)

Variable Cost U S average in 1991 was $3 88/MWh

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Table 3.2 - Inventory and Energy Production Aspects of Existing Plants in the Northwest Region

Plant Name[3]	River	Year First Unit OnLine	Plant Type	Number of Units	Total Plant Capacity (MW)	Seasonal Capacity[4] (MW)		Average Multiyear Output (billion kWh)	Capacity Factor			O&M Costs[5]	
						(Oct Mar)	(Apr Sep)		Annual (%)	(Oct Mar)	(Apr Sep)	Fixed ($/kW/yr)	Variable ($/MWhr)
1 Volkhovskaya	Volkhov	1926	RR	8	66	17.5	23.4	0.36	62	42.7	57.3	15.76	3.88
2 Niva 2	Niva	1934	RR	4	60	25.7	22.3	0.42	80	53.6	46.4	20.23	3.88
3 Nizhne Svirskaya	Svir	1936	RR	4	101.7	23.4	29.5	0.46	52	44.3	55.7	13.07	3.88
4 Nizhne Tulomskaya	Tuloma	1938	RR	4	50	22.8	9.3	0.28	64	71.1	28.9	16.18	3.88
5 Liesogorskaya (Raukhiala)	Vuoksa	1944	RR	4	108	28.3	45.2	0.64	68	38.5	61.5	17.13	3.88
6 Svetlogorskaya (Enso)	Vuoksa	1945	RR	5	100.5	27.3	42.1	0.61	69	39.3	60.7	17.54	3.88
7 Niva 3	Niva	1949	RR	4	155.5	52.1	49.0	0.89	65	51.5	48.5	16.54	3.88
8 Yaniskoski	Paz	1950	RR	3	30.45	12.0	12.0	0.21	79	50.0	50.0	19.93	3.88
9 Verkhne Svirskaya	Svir	1951	RR	4	160	28.0	32.8	0.53	38	46.0	54.0	9.57	3.88
10 Matkozhnenskaya	Vig	1952	RR	3	63	28.9	12.1	0.36	65	70.5	29.5	16.51	3.88
11 Kniazhegubskaya	Kovda	1955	RR	4	152	42.6	42.6	0.74	56	[50]	[50]	14.07	3.88
12 Narvskaya	Narova	1955	RR	3	125	35.8	30.5	0.58	53	54.0	46.0	13.41	3.88
13 Raiaskoski	Paz	1955	RR	3	43.2	12.5	12.5	0.22	58	50.0	50.0	14.72	3.88
14 Ondskaya	Vig	1957	RR	4	80	22.2	18.6	0.36	51	54.3	45.7	13.01	3.88
15 Iovskaya	Iova	1960	RR	2	80	31.2	31.2	0.55	78	[50]	[50]	19.87	3.88
16 Vigostrovskaya	Vig	1961	RR	2	40	13.5	11.7	0.22	63	53.7	46.3	15.90	3.88
17 Kumskaya	Kuma	1962	RR	2	80	19.6	19.6	0.34	49	[50]	[50]	12.28	3.88
18 Borisoglebskaya	Paz	1962	RR	2	56	15.4	15.4	0.27	55	[50]	[50]	13.93	3.88
19 Vierkhne Tulomskaya	Tuloma	1963	RR	4	268	72.9	18.2	0.80	34	80.0	20.0	8.63	3.88
20 Putkinskaya	Kem	1967	RR	3	84	23.9	23.9	0.42	57	[50]	[50]	14.45	3.88
21 Palogorskaya	Vig	1967	RR	3	30	9.2	9.2	0.16	61	[50]	[50]	15.41	3.88
22 Poduzhemskaya	Kem	1971	RR	2	48	11.2	13.7	0.22	52	45.0	55.0	13.25	3.88
23 Khevaskoski	Paz	1971	RR	2	47	7.7	16.3	0.21	51	32.0	68.0	12.91	3.88
24 Vekhne Teriberskaya	Teriberka	1984	[RR]	[?]	130	13.7	13.7	0.24	21	[50]	[50]	5.34	3.88

Table 3.2 - Inventory and Energy Production Aspects of Existing Plants in the Northwest Region

Plant Name[1]	River	Year First Unit OnLine	Plant Type	Number of Units	Total Plant Capacity[3] (MW)	Seasonal Capacity[4] (MW)		Average Multiyear Output (billion kWh)	Capacity Factor[5]			O&M Costs[6]	
						(Oct Mar)	(Apr Sep)		Annual (%)	(Oct Mar)	(Apr Sep)	Fixed ($/kW/yr)	Variable ($/MWhr)
25 Krivoporozhskaya	Kem	1990	PH	4	180	27 9	27 9	0 49	31	[50]	[50]	7 87	3 88
A Northwest Region Aggregate Plant	2 units (<30 MW)		[RR]		10	0 0	0 0	[??]		[50]	[50]		
Totals					2 348 35			10 58					

Table 3 3 - Inventory and Energy Production Aspects of Existing Plants in the Center Region

Plant Name[1]	River	Year First Unit OnLine	Plant Type	Number of Units	Total Plant Capacity[3] (MW)	Seasonal Capacity[4] (MW)		Average Multiyear Output (billion kWh)	Capacity Factor[5]			O&M Costs[6]	
						(Oct Mar)	(Apr Sep)		Annual (%)	(Oct Mar)	(Apr Sep)	Fixed ($/kW/yr)	Variable ($/MWhr)
26 Ivankovskaya	Volga	1937	[RR]		30	7 2	7 2	0 13	48	[50]	[50]	12 52	3 88
27 Uglichskaya	Volga	1940	PH		110	9 9	9 9	0 17	18	[50]	[50]	4 47	3 88
28 Ribinskaya	Volga	1941	PH		330	51 2	51 2	0 9	31	[50]	[50]	7 88	3 88
29 Nizhegorodskaya	Volga	1955	PH	8	520	80 6	80 6	1 4	31	[50]	[50]	7 78	3 88
30 Volzhskaya (after XXII Congress)	Volga	1958	RR	23	2 541	597 1	597 1	10 5	47	[50]	[50]	11 94	3 88
31 Zagorskaya 1	Kunia	1989	PS	4	800	800	800	0 80	11			2 89	3 88
B Center Region Aggregate Plant	0 units (<30 MW)		[RR]		0	0 0	0 0	0		[50]	[50]		
Totals					4 331			13 60					

Table 3 4 - Inventory and Energy Production Aspects of Existing Plants in the Middle Volga Region

Plant Name[1]	River	Year First Unit OnLine	Plant Type	Number of Units	Total Plant Capacity[3] (MW)	Seasonal Capacity[4] (MW) (Oct Mar)	Seasonal Capacity[4] (MW) (Apr Sep)	Average Multiyear Output (billion kWh)	Capacity Factor Annual (%)	Capacity Factor (Oct Mar)	Capacity Factor (Apr Sep)	O&M Costs[6] Fixed ($/kW/yr)	O&M Costs[6] Variable ($/MWhr)
32 Volzhskaya (named after Lenin)	Volga	1955	RR	20	2 300	483 5	574 5	9 3	46	45 7	54 3	11 69	3 88
33 Saratovskaya	Volga	1967	RR	24	1 360	285 6	285 6	4 95	42	[50]	[50]	10 52	3 88
34 Tcheboksarskaya	Volga	1982	PH	18	1 404	196 6	196 6	3 43	28	[50]	[50]	7 06	3 88
C Middle Volga Region Aggregate Plant	0 units (<30 MW)		[RR]		0	0 0	0 0	0		[50]	[50]	"	
Totals					5 064 00			17 68					

Table 3.5 - Inventory and Energy Production Aspects of Existing Plants in the North Caucasus Region

Plant Name[1]	River	Year First Unit OnLine	Plant Type	Number of Units	Total Plant Capacity[3] (MW)	Seasonal Capacity[4] (MW)		Average Multiyear Output (billion kWh)	Capacity Factor[5]			O&M Costs[6]	
						(Oct-Mar)	(Apr-Sep)		Annual (%)	(Oct-Mar)	(Apr-Sep)	Fixed ($/kW/yr)	Variable ($/MWhr)
35 Tsimlianskaya	Don	1926	PH	5	204	22 8	34 1	0 56	31	36 0	54 0	7 93	3 88
36 Belorechenskaya	Belaya	1961	RR	3	48	14 9	14 9	0 26	62	[50]	[50]	15 65	3 88
37 Ezminskaya	Terek	1962	RR	3	45	14 9	14 9	0 26	66	[50]	[50]	16 70	3 88
38 Tchiriutskaya	Sulak	1962	RR	2	81	29 2	29 2	0 51	72	[50]	[50]	18 20	3 88
39 Egorlikskaya	Nevinnomyssk Canal	1963	RR	[illegible]	30	5 7	5 7	0 10	38	[50]	[50]	9 63	3 88
40 Kubanskaya 1	Kuban	1967	RR	2	37	13 7	13 7	0 24	74	[50]	[50]	18 75	3 88
41 Kubanskaya 2	Kuban	1967	RR	4	184	43 2	43 2	0 76	47	[50]	[50]	11 94	3 88
42 Kubanskaya 3	Kuban	1971	PH	3	87	10 9	10 9	0 19	25	[50]	[50]	6 31	3 88
43 Kubanskaya 4	Kuban	1971	PH	3	78	9 8	9 8	0 17	25	[50]	[50]	6 30	3 88
44 Tchirkeiskaya	Sulak	1984	PH	4	1 000	125 0	125 0	2 22	25	[50]	[50]	6 42	3 88
45 Miatlinskaya	Sulak	1990	PH	2	220	36 3	36 3	0 64	33	[50]	[50]	8 41	3 88
D North Caucasus Region Aggregate Plant	13 units (<30 MW)		[RR]		166	16 6	16 6	[illegible]		[50]	[50]		
Totals					2 180			5 91					

Table 3.6 - Inventory and Energy Production Aspects of Existing Plants in the Urals Region

Plant Name[1]	River	Year First Unit OnLine	Plant Type	Number of Units	Total Plant Capacity[3] (MW)	Seasonal Capacity[4] (MW)		Average Multiyear Output (billion kWh)	Capacity Factor			O&M Costs[5]	
						(Oct Mar)	(Apr Sep)		Annual (%)	(Oct Mar)	(Apr Sep)	Fixed ($/kW/yr)	Variabl ($/MWhr)
46 Iriklinskaya	Ural	1943	PH		30	3 2	4 9	0 07	27	[40]	[60]	6 74	3 88
47 Kamskaya	Kama	1954	RR	24	504	79 6	122 0	1 76	40	39 5	60 5	10 09	3 88
48 Pavlovskaya	Ufa	1959	PH	4	166 4	22 1	34 5	0 50	34	39 1	60 9	8 68	3 88
49 Votkinskaya	Kama	1961	PH	10	1 000	108 0	162 0	2 37	27	[40]	[60]	6 85	3 88
50 Nizhn Kamskaya	Kama	1980	PH	16	1 248	119 8	179 7	2 64	24	[40]	[60]	6 11	3 88
E Urals Region Aggregate Plant	3 units (< 30 MW)		[RR]		44	4 4	4 4	[??]		[40]	[60]		
Totals					2 992 4			7 34					

Table 3.7 - Inventory and Energy Production Aspects of Existing Plants in the Siberia Region

Plant Name [1]	River	Year First Unit OnLine	Plant Type	Number of Units	Total Plant Capacity [3] (MW)	Seasonal Capacity [4] (MW)		Average Multiyear Output (billion kWh)	Capacity Factor [5]			O&M Costs [6]	
						(Oct Mar)	(Apr Sep)		Annual (%)	(Oct Mar)	(Apr Sep)	Fixed ($/kW/yr)	Variable ($/MWhr)
51 Irkutskaya	Angara	1956	RR	8	662 4	228 5	228 5	4 0	69	[50]	[50]	17 45	3 88
52 Norosibirskaya	Ob	1957	RR	7	455	113 8	113 8	1 98	50	[50]	[50]	12 58	3 88
53 Bratskaya	Angara	1961	RR	18	4 500	1 282 5	1 282 5	22 5	57	[50]	[50]	14 45	3 88
54 Mamakanskaya	Mamakan	1961	PH	4	100 2	11 5	11 5	0 2	23	[50]	[50]	5 77	3 88
55 Krasnoyarskaya	Enisei	1964	RR	12	6 000	1 110 0	1 110 0	19 58	37	[50]	[50]	9 43	3 88
56 Viliuyskaya 1	Viliuy	1967	RR	4	308	149 4	149 4	2 61	97	[50]	[50]	24 49	3 88
57 Ust Khantaiskaya	Khantaika	1970	RR	7	441	116 9	116 9	2 06	53	[50]	[50]	13 50	3 88
58 Ust Ilimskaya	Angara	1974	RR	16	3 840	1 209 6	1 209 6	21 2	63	[50]	[50]	15 96	3 88
59 Viliuyskaya 2	Viliuy	1975	RR	4	340	149 6	149 6	2 61	88	[50]	[50]	22 19	3 88
60 Saiano Shushinskaya	Enisei	1979	RR	10	6 400	1 312 0	1 312 0	23 2	41	[50]	[50]	10 48	3 88
61 Kureiskaya	Kureika	1987	RR	5	600	150 0	150 0	2 62	50	[50]	[50]	12 62	3 88
62 Maynskaya	Enisei	1982	RR	3	321	93 1	93 1	1 64	58	[50]	[50]	14 77	3 88
F Siberia Region Aggregate Plant	1 unit (<30 MW)		[RR]		3	0 3	0 3	[??]		[50]	[50]		
Totals					23 970 6			104 20					

Table 3.8 - Inventory and Energy Production Aspects of Existing Plants in the Far East Region

Plant Name[1]	River	Year First Unit OnLine	Plant Type	Number of Units	Total Plant Capacity[3] (MW)	Seasonal Capacity[4] (MW)		Average Multiyear Output (billion kWh)	Capacity Factor[5]			O&M Cost	
						(Oct Mar)	(Apr Sep)		Annual (%)	(Oct Mar)	(Apr Sep)	Fixed ($/kW/yr)	Variable ($ MWh)
63 Zeiskaya	Zeya	1975	RR	6	1 330	279 3	279 3	4 9	42	[50]	[50]	10 65	3 88
64 Kolimskaya	Kolima	1982	RR	4	720	176 4	176 4	3 08	49	[50]	[50]	12 36	3 88
G Far East Region Aggregate Plant	0 units (<30 MW)		[RR]		0	0 0	0 0	0		[50]	[50]		
Totals					2 050			7 98					

Chapter 4 MODERNIZATION AND EXPANSION OF EXISTING PLANTS

4 1 Objectives

The objective of the modernization/expansion program is two-fold First, an increase in generation capacity is gained by installing new (sometimes more efficient) turbines, generators and system controls Second, the reliability of the plant is increased by the new equipment which not only extends the project design life, but also increases the firm energy capacity of the plant

This section of the report identifies hydroelectric plants for rehabilitation modernization and expansion in the period 1995 to 2010 Certain plants have been identified for priority financial investment in the period 1995 to 1999

Throughout this section, the Project Team has investigated only upgrades to electrical and mechanical equipment in the powerhouse It has been assumed that the civil structures are in adequate condition

4 2 Evaluation Criteria

Russian counterparts on the Project Team had access to much data collected by plant personnel Several rather standard criteria, discussed below, have been used in the identification and prioritization process

4 2 1 Age

While age by itself is not a good indicator of the need for rehabilitation, it is a good screening element and when supported by other criteria, it lends credibility to the identification process State standard norm GOST 26945-86 for turbines and GOST 5616-81 for generators establish a "normal" service life of 40 years for turbines and generators

4 2 2 Unusually Large Maintenance Requirements

Rather detailed records are kept of equipment maintenance requirements including equipment outage times forced outages and costs of repairs Sufficient data exists to establish maintenance norms Data for individual pieces of equipment is tracked and compared to norms to establish the need for more detailed analysis, such as a feasibility report

4 2 3 Tests

Standard tests used to evaluate equipment condition are the following

- a Temperature of the generator and turbine bearings
- b Vibration of the basic components of the turbine or generator
- c Acoustic measurements in the runner's chamber
- d Turbine efficiency by an absolute method
- e Temperature measurement of the front parts of the stay ring by remote pyrometers
- f Measurement of the stress levels of the unit s basic components
- g Measurement of the requirement forces by the governing system
- h Insulation tests of the generator's circuits and windings

4 2 4 Evaluation by Hydro Experts

The above data is reviewed by resident experts familiar with the equipment and system needs to determine the appropriate priority for investment and/or the need for additional study

4 3 Assessment of Existing Plants Currently Under Rehabilitation Reconstruction

Many Russian hydroelectric plants are currently undergoing some type of rehabilitation or upgrade as part of the system's long-term operation and maintenance program Certain plants have been identified for financial investment to accelerate the realization of energy benefits The plants identified by the above process are listed in **Table 4 1** These plants are currently undergoing some type of rehabilitation construction The required financial investment to continue the rehabilitation/modernization program at these plants is shown on **Table 4 2**

Table 4 1 - Priority Projects to Continue Rehabilitation/Expansion Construction Characteristics

Existing Plant	Region	Generation Capacity (MW)		Avg Annual Energy (billion kWh)	
		Before Rehab	After Rehab	Before Rehab	After Rehab
Nizhne-Tulomskaya	Northwest	50	57	0 28	0 31
Volzhskaya (named after Lenin)	Middle Volga	2 300	2 400	9 30	10 9
Volzhskaya (after XXII Congress)	Center	2 541	2 649	10 52	11 1
TOTALS		4 891	5 106	21 26	23 92

Table 4 2 - Priority Projects to Continue Rehabilitation/Expansion Construction Investment Plan

Existing Plant	Investment Requirement Billion $ (1991 US$=1Rb)					
	1995	1996	1997	1998	1999	Total
Nizhne-Tulomskaya						
Cash Flow %	20%	50%	30%	--	--	100%
Investment billion US$	0050	0125	0075			0250
Plant Capacity MW	50	54	57	57	57	57
Volzhskaya (named after Lenin)						
Cash Flow %	15%	20%	30%	20%	15%	100%
Investment billion US$	0375	0500	0750	0500	0375	2500
Plant Capacity MW	2300	2325	2350	2375	2400	2400
Volzhskaya (after XXII Congress)						
Cash Flow %	15%	20%	30%	20%	15%	100%
Investment billion US$	0375	0500	0750	0500	0375	2500
Plant Capacity MW	2541	2568	2595	2622	2649	2649
TOTALS						
Cash Flow %	15%	21%	30%	19%	15%	100%
Investment billion US$	0 0800	0 1125	0 1575	0 1000	0 0750	5250
Plant Capacity MW	4891	4947	5002	5054	5106	5106

4 4 Assessment of Existing Plants to Start Rehabilitation Reconstruction

In addition to those plants currently under rehabilitation the Project Team has identified twenty-five (25) plants for rehabilitation/expansion in the period 1995 to 2010 as shown on **Table 4 3** These plants have been selected based on the evaluation criteria presented above It should be assumed that without rehabilitation these plants will be out of service by the year 2010 The twenty-five plants account for 5 718 75 MW installed nameplate capacity with an annual average energy production of 19 90 billion kWh

Table 4 3 - Projects to Start Rehabilitation/Expansion Before the year 2010

Plant Name	Region	River	Maximum Head (m)	Existing Capacity (MW)	Average Multiyear Output (billion kWh)	Reservoir Storage (million m³)
Niva 2	Northwest	Niva	38 5	60	0 42	43
Nizhne Svirskaya	Northwest	Svir	13 8	101 7	0 46	0 023
Lesogorskaya (Raukhiala)	Northwest	Vuoksa	17 8	108	0 64	0 006
Svetlogorskaya	Northwest	Vuoksa	17 1	100 5	0 61	0 01
Niva 3	Northwest	Niva	79	155 5	0 89	0 0015
Yaniskoski	Northwest	Paz	22 2	30 45	0 21	0 004
Verkhne Svirskaya	Northwest	Svir	17	160	0 53	12 7
Matkozhnenskaya	Northwest	Vig	23 6	63	0 36	0 017
Narvskaya	Northwest	Marpva	25	125	0 58	2
Rayaskoski	Northwest	Paz	19 8	43 2	0 22	0 008
Ondskaya	Northwest	Vig	29 2	80	0 36	5 14
Vigostrovskaya	Northwest	Vig	14 1	40	0 22	0 002
Verkhne Tulomskaya	Northwest	Tuloma	62	268	0 80	3 86
Volkhovskaya	Northwest	Volkhov	12	66	0 36	[illegible]
Uglitchskaya	Center	Volga	16	110	0 17	800
Ribinskaya	Center	Volga	18	330	0 9	16700
Nizhegorodskaya	Center	Volga	17	520	1 41	2 78
Saratovskaya	Center	Volga	15	1 360	4 95	1 75
Tsimlianskaya	North Caucasus	Don	26 6	204	0 56	10
Beloretchenskaya	North Caucasus	Belava	52 7	48	0 26	0 01

Table 4 3 - Projects to Start Rehabilitation/Expansion Before the year 2010

Plant Name	Region	River	Maximum Head (m)	Existing Capacity (MW)	Average Multiyear Output (billion kWh)	Reservoir Storage (million m³)
Ezminskaya	North Caucasus	Terek	170	45	0 26	0 00023
Egorlikskaya	North Caucasus	Nevinnomissk Canal	31 8	30	0 1	0 095
Kamskaya	Urals	Kama	15 5	504	1 76	9200
Pavlovskaya	Urals	Ufa	32 9	166 4	0 5	900
Votkinskaya	Urals	Kama	23	1 000	2 37	3 7
TOTALS				5718 75	19 90	

In reviewing the circumstances of these twenty-five plants requiring rehabilitation, four plants have been identified for priority investment in the period 1995-1999 as shown on **Table 4 4** Without rehabilitation these plants will be out of service by the year 2000 The required financial investment for the rehabilitation/modernization of these plants is shown on **Table 4 5**

The following sections present a further discussion of the four priority plants for rehabilitation

Table 4 4 - Priority Projects to Start Rehabilitation/Expansion Characteristics

Plant Name	Region	Capacity (MW)		Output (Billion kWh)	
		Before Rehab	After Rehab	Before Rehab	After Rehab
Kamskaya	Urals	504	552	1 760	1 800
Volkhovskaya	Northwest	66	96	0 360	0 410
Pavlovskaya	Urals	166 4	180	0 500	0 503
Uglitchskaya	Center	110	126	0 170	0 178
TOTALS		846 4	954	2 790	2 891

Table 4 5 - Priority Projects to Start Rehabilitation/Expansion Investment Plan

Plant Name		Investment Requirement Billion $ (1991 US$=1Rb)					
		1995	1996	1997	1998	1999	Total
Kamskaya	Cash Flow %	15%	20%	30%	20%	15%	100%
	Cash Flow billion US$	036	048	072	048	036	240
	Plant Capacity MW	504	516	528	540	552	552
Volkhovskaya	Cash Flow %	15%	35%	35%	15%		100%
	Cash Flow billion US$	009	021	021	009		060
	Plant Capacity MW	66	76	86	96	96	96
Pavlovskaya	Cash Flow %	20%	50%	30%			100%
	Cash Flow billion US$	004	010	006			020
	Plant Capacity MW	166	173	180	180	180	180
Uglitchskaya	Cash Flow %	20%	50%	30%			100%
	Cash Flow billion US$	017	0425	0255			085
	Plant Capacity MW	110	118	126	126	126	126
TOTALS							
	Cash Flow %	16%	30%	31%	14%	9%	100%
	Cash Flow billion US$	066	1215	1245	057	036	405
	Plant Capacity MW	846	883	920	942	954	954

4 4 1 Kamskava Plant

The Kamskaya Hydroelectric Plant located on the River Perm, is one of the four plants of the Kamskry cascade The plant controls loads during 24 hours a day The plant's construction began in 1948 and was completed in 1958 The first unit was commissioned in 1954

The Kamskaya Plant is operated by the Joint-Stock Company (JSC) "Permanargo" The equipment data and the design energy indicators for Kamskava plant are presented in the Stage 1 Report (**Appendix A**) The plant's structure includes a combined hydroelectric plant a bed dam and a flood-lands dams, and a six-chamber-two-line lock

The plant's combined spillway/powerhouse structure was the first of its kind This type of structure together with numerous relatively small units, afforded minimum depth of the structures base which was extremely important because of complex geological conditions of the dam site and a sufficiently wide spillway front

<u>4 4 1 1 Existing Condition</u> The powerhouse structure is in good condition The bed- and flood-lands dams have a total length of 1828 meters and are made of gravel-type soil and fine grained gravel, mainly of limestones and argil, hydraulically deposited The dam's slopes are anchored by reinforced concrete slabs and crushed rock and crushed stones The land structures of the hydroelectric scheme are in satisfactory condition

The plant's equipment has been in service for some 40 years and is requiring more and more maintenance especially because the powerhouse is combined with a spillway The results of field tests show that, given the existing regimes of the units usage (as far as the capacity and the head are concerned), the turbine's ratings do not measure up to an optimal work mode at a universal performance As a result of severe cavitation erosion, the runners and the cases were clad many times with stainless plates and stainless wire was deposited by welding on them that changed completely their original shape Pieces of the case s inner side were pulled out and there were cracks Runner blades are broken in many places The process of crack formation is accelerating Due to deformations and wear of the penstocks the turbine absolute efficiency level is less than that guaranteed by the manufacturer All the components of the turbine and auxiliary equipment show extensive wear

The babbitt surfaces of the generator s thrust bearing segments have cracks and some dents The thrust bearing tank gaskets are not air-tight and let oil vapors escape During previous maintenance periods all oil and air coolers were changed and the generator's exciters were replaced

An overall inspection of the mechanical equipment revealed numerous defects and design flaws in several structures The use of repair gates designed for turbines in case of an emergency is hindered by the lack of heating and by the worn out condition of the support and running components (that is a characteristic feature of other gates, too) The turbine gate seal is not a tight fit and for this reason cannot be used for repairs The gratings are the cause of big differentials and are inconvenient (some have already been replaced with new ones)

The gantry cranes manufactured in the former German Democratic Republic (GDR) show extensive wear and are unreliable The same is true for the electrical equipment of the rest of the cranes All the plant's locks are of sliding action The support rails and slides have been poorly made of wood according to an obsolete design that results in faster wear and tear of the runners

4 4 1 2 Transmission The plant s energy output is transmitted by 3 power lines of 220 kV and 10 power lines of 110 kV

4 4 1 3 Rehabilitation The following sections describe the planned rehabilitation measures

4 4 1 3a Basic and Auxiliary Equipment The following describes the basic and auxiliary equipment to be replaced as currently planned

1 Replacement of the old runners with new ones will not only decrease unplanned outages of the turbines but will also increase their theoretical and actual efficiency by some 3 to 4% and augment a unit's capacity to 24 8 MW and increase the energy output as well The replacement of runner blades will be done as a major repair
2 Replacement of the runner cases lines
3 Replacement of turbines' governors with more modern ones capable of providing the control required by modern power systems

4 Replacement of turbine guide vanes with steel vanes and cladding trunnions with stainless steel

5 Replacement of pumps and pressure tanks of the oil-pressure set with new ones

6 Installation of additional air cooler sets, replacement of oil cooling of the generator bearings and replacement of their sump tanks

7 Replacement of the babbitt segments of the generators thrust bearing with new ones

8 Replacement of the equipment reinforcing bars and water pipe lines of the water supply system for technical purposes

9 Replacement of the equipment and reinforcing bars of the pneumatic facilities of the plant and (?????)

10 Replacement of the technical system of driving the hydraulic units into a synchronous condenser regions

11 Replacement of the equipment reinforcing bars and water pipe lines of the drainage system of the water passages with new ones

12 Completion of the (facilities?????) with oil refining devices for a degassing and oil drying

4 4 1 3b Electrical and Technical Equipment The following describes the electrical and technical equipment to be replaced as currently planned

1 Replacement of the generator's stay ring winding with thermosetting insulation winding in accordance with the project design that provides for a generator s capacity increase by 15% (the self-contained transformers have been already redesigned and their certificate capacity can be increased up to 60000 KWA)

2 Replacement of machine excitation of the generators by a thyristor one

3 Replacement of a frame and connection insulation of a rotor poles

4 Replacement of a ventilation system of hydroelectric generators

5 Replacement of a generator distribution device

6 Replacement of generator lead wires

7 Replacement of automatic equipment panels, protection and generator excitation panels

8 Replacement of protection panels of the self-contained transformers, 110 kV and 220 kV

9 Replacement of some of the power panels
10 Laying power and control cables
11 Partial removal of the existing power and control cables

4 4 1 4 Rehabilitation Cost and Energy Improvements

In the rehabilitation process it is planned to replace parts and components of a basic and auxiliary equipment so that the efficiency of units and their individual capacity could be increased After the rehabilitation, the plant's design capacity will increase from 504 MW to 552 MW and the energy output will be 1 800 billion kWh compared to 1 740 billion kWh of original design capacity The energy output of the plant will be higher because of a higher efficiency of equipment and reduction of idle discharges to the plant's tailwater

By 1994 the service life of the plant s basic equipment was 36 to 40 years A capacity increase of plant after the rehabilitation will become possible thanks to its augmented design increase and to an improvement of functioning of the basic equipment which is in a dangerous state

The Kamskaya Plant rehabilitation cost is estimated at $240 3 million (1991) as shown in **Table 4 6**

4 4 1 4 Economics The efficiency of the Kamskaya Plant rehabilitation has been determined by comparing the amount of the investments needed for rehabilitating the plant with the net profit derived from the rehabilitated plant The energy rate for the plant's output has been calculated on the capacity and energy basis The economic effect is assessed on the basis of an increased capacity and the energy output taking into account its dynamics by years The internal rate of return for the project is estimated at 16 2%

Table 4 6 - Estimated Rehabilitation Costs for the Kamskaya Plant

Item Number	Description	Estimated Cost $million (1991)
1	Mobilization/Demobilization	0 17
2	Powerplant	12 96
3	Turbine and Generator	126 98
4	Auxiliary Electrical System	44 95
5	Miscellaneous Mechanical Equipment	23 14
	SUBTOTAL DIRECT COST	208 20
6	Contingency (Civil Electrical and Mechanical)	29 45
7	Administration, Engineering and Construction Services	2 65
	TOTAL CONSTRUCTION COST	240 30

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4 4 2 Volkhovskava Plant

The Volkhovskava Hydroelectric Plant is located in St Petersburg Province about 197 5 km from the place the River Volkhov originates flowing out of the Lake Ilmen and 26 5 km from the place it flows into the Lake Ladechaleova The construction of the plant began in 1919 and was finished in 1926 (according to the GOELRO plan - State Electrification of Russia) The Plant is operated by the JSC "LENENERGO"

The equipment data and the design energy indicators for the plant were provided in the Stage 1 Report which is attached as Appendix A

The plant's structure includes the powerhouse, a spillway dam, a floodgate an ice protection wall a one-chamber lock and one lock for fish passage The foundation of the plant's structures lays in limestone The powerhouse is of a bed type (founded on rock) The structures' status of the plant meets the present-day demands for using the plant

The spillway dam is located between the left bank of the River Volkhov and the powerhouse Originally the dam was designed and built for a free spillway of increasing flow of water over the dam crest

In 1970-1971 piers were built and gates were placed and then a bridge was built over the piers for a gantry crane and pedestrians

4 4 2 1 Existing Condition The Volkhovskava Plant became operational in 1926 and again after it was restored in 1942-1945 The results of a technical study made in 1972 showed that the basic hydraulic power and mechanical equipment as well as some of the electrical equipment were obsolete and outdated and had to be replaced

At the request of the Fuel and Energy Ministry of 11-Jan-1985, the Leningrad branch of the "Gidroproject" Institute made in 1985-1987 a design for the Volkhovskava Plant rehabilitation and named for V I Lenin

4 4 2 2 Rehabilitation The following sections describe the planned rehabilitation measures

4 4 2 2a Hydraulic Turbines There are 8 main radial-axis turbines in service at the plant 8 MW capacity each with a head of 12 meters and 2 auxiliary turbines 1 MW each (the latter work for the plant itself) According to the plant's rehabilitation design the main turbines and generators, given their wear and tear, have to be replaced but parts of the old foundations would be used All working parts, and governors of the turbines need to be replaced

The auxiliary units are completely worn out and should be decommissioned

In accordance with the request because of the replacement of the generators and usage of a closed-circuit cooling system the rehabilitation design of the plant has to provide for a new water supply system for technical needs A replacement of a compression equipment for technical needs of the plant and charging or turbines is provided for too

The crane in the powerhouse cannot be used any longer and should be removed At present a new, standard crane has been installed

4 4 2 2b Hydraulic Generators There are 8 basic generators in service with a rated capacity 8 MW/8 75 MVA and a voltage of 11 kV each There is a separate electric machine excitation system for the generators equipped with electric motors TGTM-127/6 and GM-302 exciters According to the results of a technical inspection of the plant that was supported later by the aforementioned studies the basic generators and their excitation system are to be replaced

LPEO (Leningrad) "Electrosila" suggests a design for the Volkhovskaya plant that provides for 8 generators with a rated capacity of 16 MW, a rated voltage of 10 5 kV and thyristor excitation system

4 4 2 2c Electrical and Technical Equipment All the obsolete and worn out equipment of (3PY) and (OPY) of 110 kV, that is oil breakers, current and voltage transformers, has been replaced during overhauls with modern oil breakers made by "ASEA" company and with current and voltage transformers made in this country The disconnects were left in place and there are no plans to replace them

It is envisaged to eliminate during the rehabilitation the new open part located on top of the power-house roof on a metal trestle This (OPY) of 110 kV has changed a unique architectural form of the Plant s power-house

4 4 2 3 Rehabilitation Cost and Energy Improvements After the turbines are replaced by new ones the plant's capacity during maximum loads in the guaranteed (by the head) conditions will be 72 MW A runner increase of the generators capacity makes it possible not to limit the turbine's capacity at increased heads and to get an additional energy output that will be 13 million kWh (an increase from 392 million kWh to 405 kWh) at an increased capacity up to 96 MW (an ultimate head for this kind of turbine)

The plant's rehabilitation will take 5 years, because during the process it is supposed to be in service and no more than two units can be out at any one time while during flood periods all eight units have to be in operation (the existing and the newly installed ones)

The total rehabilitation cost of the plant is $60 million (1991) as shown in **Table 4 7**

4 4 2 4 Economics The efficiency of the Volkhovskaya Plant's rehabilitation has been determined by comparing the amount of investments needed for rehabilitating the Plant with a net profit derived from the energy sold The energy rate for the electricity sold directly from the Plant's wires has been calculated on the capacity and the output basis

The economic effect is estimated on the basis of an increased capacity and energy output taking into account its dynamics by years The internal rate of return to the project is estimated at 23 7%

Table 4 7 - Estimated Rehabilitation Costs for the Volkhovskava Plant

Item Number	Description	Estimated Cost $million (1991)
1	Mobilization/Demobilization	0 020
2	Reservoir and Dams	0 068
3	Powerplant	10 590
4	Turbine and Generator	39 330
5	Auxiliary Electrical System	0 900
6	Miscellaneous Mechanical Equipment	1 400
SUBTOTAL DIRECT COST		52 308
7	Contingency (Civil, Electrical and Mechanical)	5 060
8	Administration, Engineering and Construction Services	2 632
TOTAL CONSTRUCTION COST		60 000

4 4 3 Pavlovskava Plant

4 4 3 1 Basic Data The Pavlovskava Hydroelectric Plant is located on the Ufa River The plant is operated by the JSC 'Bashkirenergo" The construction began in 1950 and was finished in 1961 The first unit was commissioned in 1959 The equipment data and the design energy indicators for the Pavlovskaya Plant were provided during the work Stage 1 (**Appendix A**)

The scheme's structure includes a powerhouse combined with a spillway, a bed- and flood-lands dams and (OPY) of 110 kV and 35 kV The powerhouse is a combined with four surface spillways equipped with work and repair flat wheel two-chamber gate a water-intake structure with trashracks and repair gates installed ahead of the turbines The combined spillway/powerhouse of the plant has an efficient and well planned layout

Adjacent to the powerhouse is a one-chamber shipping lock that can be used for water discharge at a design flood of 0 1% of the supply A considerable part of the equipment which has been in operation for a long time, has become obsolete and very worn It has been discontinued and there are no spare parts available

4 4 3 2 Existing Condition During the operation period of the plant a considerable amount of turbine research has been done that makes it possible to improve their performance New stainless (???) 50/1075 runner blades have been designed for the Pavlovskaya Plant that make it possible to increase the efficiency at maximum output by 2% and by 3% at the design point output The new blades also offer an increased turbine capacity -from 42 5 MW to 52 MW (with a higher generator's power factor) - at a maximum head of 32 m The runner cases have considerable cavitation wear There were cases when the line(???) was pulled out

The demountable part of the runner's case was not used for the design purposes and at present reduces the runner's case reliability The lignumvitae bushings of the blades bearing of the guiding device are considerably worn out The governor PK-160 is obsolete There are no turbine meters in the measurement system at a unit, the cross-head meters are out of service The upper gasket of the generators bearing oil tub is not a tight fit The support bolts of the thrust bearings are outdated The brakes shoes are old "ferrado" type pads While the generators were in use they were modernized and reequipped The existing worn-out and obsolete generators excitation system needs to be replaced by a thyristor one

4 4 3 3 Rehabilitation Cost and Energy Improvements The Pavlovskaya Plant rehabilitation plans provide for a replacement of parts and components of the basic as well as the auxiliary equipment in order to increase units efficiency by 2 to 3% and their individual capacity from 41 6 MW to 45 MW The plant's capacity will increase after the rehabilitation from 166 4 MW to 180 MW that is by 13 6 MW while the energy output will increase from 0 500 billion kWh (the design figure) to 0 503 billion kWh The energy output growth is ensured by an increase in the equipment efficiency and by a reduction of idle discharges to the Plant's tailwater

By 1994 the service life of the plants' basic equipment was 35 to 36 years A capacity increase of the plant after the rehabilitation is ensured by an increase in the plant's design capacity and by an improvement of the functioning of the basic equipment which is in an emergency state The major rehabilitation work at the Pavlovskaya Plant is planned to do in 4 years

The Pavlovskaya Plant rehabilitation cost is estimated at $20 million (1991) as shown in **Table 4 8**

4 4 3 4 Economics The Pavlovskaya Plant rehabilitation efficiency has been determined by comparing the amount of the investments needed for the plant's rehabilitation with the net profit ensured by the rehabilitation The energy rate for the plant s output at its wires has been calculated on the capacity and energy basis The economic effect is assessed on the basis of an increased capacity and the energy output taking into account its dynamics by years

The internal rate or return for the project is estimated at 20 4%

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Table 4 8 - Estimated Rehabilitation Costs for the Pavlovskaya Plant

Item Number	Description	Estimated Cost $million (1991 US$)
1	Mobilization/Demobilization	0 030
2	Turbine and Generator	0 980
3	Auxiliary Electrical System	6 900
4	Miscellaneous Mechanical Equipment	7 350
SUBTOTAL DIRECT COST		15 260
5	Contingency (Civil Electrical and Mechanical)	2 950
6	Administration, Engineering and Construction Services	1 790
TOTAL CONSTRUCTION COST		20 000

4 4 4 Uglitchskaya Plant

4 4 4 1 Basic Data The Uglitchskaya Hydroelectric Plant is located on the Volga River The plant is operated by the JSC "Yarenergo" The first unit was commissioned in 1940 The equipment data and the design energy indicators for the Plant were provided in the Stage 1 Report (**Appendix A**)

The scheme's structures include a powerhouse a spillway dam, a bed-earth dam a shipping lock and (OPY) of 220 kV and 35 kV

4 4 4 2 Existing Condition There are two units with ????-91-900 turbines and CB-1250/170-96 generators of 55 MW capacity The units were commissioned in 1940 and 1941 but are still in a working condition, although significantly worn There are accidents of cone breakage and blades destruction multiple damage of the runners cases cavitation destruction of working heads, oil leakage through the blades seals, wear of the turbines bearings and blades' bearings of the guiding devices The design and performance data of the runners are obsolete The systems of the turbines governing and the generators excitation are obsolete also and do not comply with the working requirements of the current energy system

The mechanical equipment of the Uglitchskaya Plant has been in operation for more than 45 years and has not been under a major repair Its composition and layout do not comply fully with necessary standards that match the present-day design standards On a request of the Fuel and Energy Ministry the Kuybishev branch of the "GIDROPROJECT" made in 1988 a feasibility study entitled "Technical Reequipment and Rehabilitation of the Uglitchskaya Plant on the Volga River"

4 4 4 3 Rehabilitation Cost and Energy Improvements Rehabilitation of the plant including new equipment will allow preservation a significant energy source in the system, make the plant more reliable and increase its energy output

A replacement of the basic technical equipment will make it possible to increase the plant's design capacity from 110 MW to 117 MW and the energy output from 168 million kWh (the design figure) to 178 million kWh The energy output growth is ensured by an increase in the equipment efficiency and by a reduction of idle discharges to the plant's tailwater

By 1994 the service life of the plant's basic equipment was 53 to 55 years A capacity increase of the plant after the rehabilitation is ensured by an increase in the design capacity and by an improvement of the functioning of the basic equipment in an emergency condition

The Uglitchskaya Plant rehabilitation cost is estimated at $85 714 million (1991) as shown in **Table 4 9**

Table 4 9 - Estimated Rehabilitation Costs for the Uglitchskaya Plant

Item Number	Description	Estimated Cost $million (1991 US$)
1	Mobilization/Demobilization	0 114
2	Reservoir and Dams	13 900
3	Powerplant	5 000
4	Turbine and Generator	30 120
5	Auxiliary Electrical System	15 390
6	Miscellaneous Mechanical Equipment	5 840
SUBTOTAL DIRECT COST		70 364
7	Contingency (Civil, Electrical and Mechanical)	13 860
8	Administration Engineering and Construction Services	1 490
TOTAL CONSTRUCTION COST		85 714

4 4 4 4 Economics The rehabilitation efficiency of the Uglitchskaya Plant has been determined by comparing the amount of the investments needed for the plant's rehabilitation with the net profit ensured by the rehabilitation The energy rate for the plant's output on its wires has been calculated on the capacity and energy basis

The economic effect is assessed on the basis of an increased capacity and the energy output taking into account its dynamics by years The computed internal rate of return for the project is estimated at 13 1%

4 5 Summary and Conclusion

The Project Team has identified three priority hydroelectric plants which are currently undergoing rehabilitation for financial investment to complete construction in an expedited manner These three plants - Nizhne-Tulomskaya, Volzhskaya (named after V I Lenin), and Volzhskaya (named after XXII Congress) - require approximately $525 million over the five year period 1995 to 1999

The Project Team has identified a total of twenty-five hydroelectric plants requiring rehabilitation prior to 2010 Without rehabilitation, these plants identified in **Table 4 3** will likely have to be taken out of service by the year 2010 The Project Team has identified four plants - Kamskaya Volkhovskaya Pavlovskaya, and Uglitchskaya - for priority financial investment for rehabilitation since these projects are in the most critical condition Without rehabilitation the four priority plants will likely be out of service by the year 2000 The estimated investment requirement for rehabilitation of the four priority plants is $405 million

Rehabilitation of the selected priority plants will guarantee the supply of energy from these plants by extending their service lives Rehabilitation will also increase the nameplate capacity approximately 322 6 MW (from 5737 4 to 6060 MW) and average annual energy production by approximately 2 761 billion kWh (from 24 05 to 26 811 billion kWh) as shown in **Table 4 10** The total investment requirement for rehabilitation/expansion of existing plants is $930 million over the period 1995 to 1999 as shown in **Table 4 11**

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Table 4 10 - Priority Projects for Rehabilitation/Expansion Reconstruction Characteristics

Existing Plant	Plant Status	Region	Generation Capacity (MW)		Avg Annual Energy (billion kWh)	
			Before Rehab	After Rehab	Before Rehab	After Rehab
Nizhne-Tulomskava	1	Northwest	50	57	0 28	0 31
Volzhskaya (named after Lenin)	1	Middle Volga	2 300	2 400	9 30	10 9
Volzhskaya (after XXII Congress)	1	Center	2 541	2 649	10 52	11 1
Kamskava	2	Urals	504	552	1 760	1 800
Volkhovskaya	2	Northwest	66	96	0 360	0 410
Pavlovskaya	2	Urals	166 4	180	0 500	0 503
Uglitchskaya	2	Center	110	126	0 170	0 178
TOTALS			5737 4	6060 0	24 05	26 811

Note Plant Status Definition

"1" = Existing plant currently under rehabilitation Investment required to complete ongoing construction

"2" = Existing plant with rehabilitation work under design Investment required to start rehabilitation construction

Table 4 11 - Priority Projects for Rehabilitation/Expansion Construction Investment Plan

Existing Plant	Investment Requirement Billion $ (1991 US$=1Rb)					
	1995	1996	1997	1998	1999	Total
Nizhne-Tulomskaya						
Cash Flow %	20%	50%	30%	--	-	100%
Investment billion US$	0050	0125	0075			0250
Plant Capacity MW	50	54	57	57	57	57
Volzhskaya (named after Lenin)						
Cash Flow %	15%	20%	30%	20%	15%	100%
Investment billion US$	0375	0500	0750	0500	0375	2500
Plant Capacity MW	2300	2325	2350	2375	2400	2400
Volzhskaya (after XXII Congress)						
Cash Flow %	15%	20%	30%	20%	15%	100%
Investment billion US$	0375	0500	0750	0500	0375	2500
Plant Capacity MW	2541	2568	2595	2622	2649	2649
Kamskaya Cash Flow %	15%	20%	30%	20%	15%	100%
Cash Flow billion US$	036	048	072	048	036	240
Plant Capacity MW	504	516	528	540	552	552
Volkhovskaya Cash Flow %	15%	35%	35%	15%		100%
Cash Flow billion US$	009	021	021	009		060
Plant Capacity MW	66	76	86	96	96	96
Pavlovskaya Cash Flow %	20%	50%	30%			100%
Cash Flow billion US$	004	010	006			020
Plant Capacity MW	166	173	180	180	180	180
Uglitchskaya Cash Flow %	20%	50%	30%			100%
Cash Flow billion US$	017	0425	0255			085
Plant Capacity MW	110	118	126	126	126	126
TOTALS						
Cash Flow %	16%	25%	30%	17%	12%	100%
Cash Flow billion US$	146	234	282	157	111	930
Plant Capacity MW	5737	5830	5922	5996	6060	6060

Chapter 5 COMPLETION OF NEW PLANTS

5 1 Objectives

Several hydroelectric projects were under construction at the time of the breakup of the former Soviet Union in 1991 Almost immediately, federal funding of these projects was halted However, construction has continued at some of these projects at a very slow pace utilizing the financial resources of local owner/operator Joint Stock Companies (JSC) which were formed to operate and maintain the Russian hydroelectric plants

5 2 Assessment of New Plants Currently Under Construction

Several hydroelectric power plants are currently under construction in the Russian Federation The Project Team has identified six priority plants for investment in the period 1995 to 1999 In selecting priority plants for investment, the Project Team considered political, technical, environmental transmission lines, and economical factors of each project Plants which are currently under construction have the advantage that much of the labor and construction equipment mobilization costs have previously been sunk Therefore, the remaining costs to complete these projects are attractive considering the high return in generation capacity and energy production potential

During Stage 1 of this assignment, the Project Team analyzed three plants currently under construction These plants were Aushigerskaya Plant (57 MW), Zelentchukskaya Plant (262 MW), and the Zaramagskaya Plant (342 MW) These three plants are all located in the Northern Caucasus Region Aushigerskaya in the Republic of Kabardino-Balkaria, Zelentchukskaya in the territory of the Laratchaevo-Tcherkessia Republic, and Zaramagskay in the territory of the Republic of Severnaya (North) Osetia Detailed information on the equipment and characteristics of these plants is given in the Stage 1 Report attached as **Appendix A**

During Stage 2, three other plants currently under construction were identified as priority projects for completion. The projects are the Zagorskaya-1 (Stage 1) Pumped-Storage Plant (1200 MW) in the Center Region near Moscow, the Bogutchanskaya Plant (3000 MW) in Siberia, and the Bureyskaya Plant (2000 MW) in the Far East.

All six projects are currently under construction at a slowed pace due to lack of financing. Of these six projects, only Zagorskaya-1 is currently generating power with four of six units on-line (800 MW out of 1200 MW). **Table 5.1** shows the project characteristics of the six priority plants. **Table 5.2** shows the investment requirements to complete construction of these plants. The following sections present a discussion of the basis for selecting these six plants for priority investment.

Table 5.1 - Priority New Plants to Finish Ongoing Construction Characteristics

Plant Name	Region	Capacity (MW)		Output (billion kWh)	
		Before Rehab	After Rehab	Before Rehab	After Rehab
Aushigerskaya	North Caucasus	0	57	0	0.236
Zelentchukskaya	North Caucasus	0	262	0	0.769
Zaramagskaya	North Caucasus	0	342	0	0.789
Zagorskaya PS 1	Center	800	1200	0.800	1.200
Bogutchanskaya	Siberia	0	3000	0	17.6
Bureyskaya	Far East	0	2000	0	7.1
TOTALS		800	6861	0.800	27.694

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Table 5 2 - Priority New Plants to Finish Ongoing Construction Investment Plan

Plant Name	Investment Requirement Billion $ (1991 US$=1Rb)							
	1995	1996	1997	1998	1999	2000	2001	Total
Aushigerskaya								
Cash Flow %	20%	50%	30%	-		--	--	100%
Cash Flow billion US$	0206	0515	0309					0 103
Plant Capacity MW	0	0	57	57	57	57	57	57
Zelentchukskaya								
Cash Flow %	10%	20%	30%	30%	10%	--	--	100%
Cash Flow billion US$	0204	0408	0612	0612	0204			0 204
Plant Capacity MW	0	0	60	160	262	262	262	262
Zaramagskaya								
Cash Flow %	10%	20%	30%	30%	10%		-	100%
Cash Flow billion US$	0233	0466	0699	0699	0233			0 233
Plant Capacity MW	0	0	57	228	342	342	342	342
Zagorskaya PS - 1								
Cash Flow %	20%	50%	30%	-	-	--	--	100%
Cash Flow billion US$	020	050	030					100
Plant Capacity MW	800	1000	1200	1200	1200	1200	1200	1200
Bogutchanskaya								
Cash Flow %	10%	15%	15%	15%	15%	15%	15%	100%
Cash Flow billion US$	140	210	210	210	210	210	210	1 400
Plant Capacity MW	0	0	0	666	1666	2666	3000	3000
Bureyskaya								
Cash Flow %	10%	15%	15%	15%	15%	15%	15%	100%
Cash Flow billion US$	220	330	330	330	330	330	330	2 200
Plant Capacity MW	0	0	0	342	1026	1700	2000	2000
TOTALS								
Cash Flow %	10%	17%	17%	16%	14%	13%	13%	100%
Cash Flow billion US$	4443	7289	732	6711	5837	540	540	4 240
Plant Capacity MW	800	1000	1374	2653	4553	6227	6861	6861

5 2 1 Aushigerskaya Plant

The Aushigerskaya Plant is located on the River Tcherek in the Kabardino-Balkaria Republic of the North Caucasus Region of the Russian Federation The planned design capacity of this plant is 57 MW with an average annual energy production of 0 236 billion kWh This project is designated as Priority No 1 for investment of the "plants currently under construction" for the following reasons

- a The Kabardino-Balkaria Republic has a current energy deficit,
- b There is overwhelming political support for this project from both the Republic's government and the President of Russia,
- c The plant is located near existing transmission line systems,
- d The estimated $103 million (1991) project costs are attractive for foreign investment and
- e The project has a attractive rate of return for the required investment

5 2 1 1 Owner/Operator The Aushigerskaya Plant is owned by the JSC "EeC Poccuu" The energy produced by the plant will be sold to the JSC "Kabbalkenergo" to supply power to the Kabardino-Balkaria Republic Currently, the Kabbalkenergo power system lacks power to supply energy to the Republic The Republic's existing hydroelectric plants can supply only 7% of the region's required energy The deficit power is transmitted to Kabbalkenergo from JSC Starzopol Region

5 2 1 2 Political Aspects In all of Russia the political administration of the Kabardino-Balkaria Republic is the most interested in construction of hydroelectric schemes in general and in completing the Aushigerskaya Plant construction in particular This is because there are no fossil fuel resources in the Republic and the construction of hydroelectric schemes, including the Aushigerskaya Plant, is viewed as a basis of the Republic's energy sector development and its future social and economic development

The selection of the construction site for the Aushigerskaya Plant was approved by the Council of Ministers of Kabardino-Balkazia on 10-July-1980 The design of the Aushigerskaya Hydroelectric Plant was approved by the Order No 190, paragraph C of Ministry of Fuel and Energy of the Russian Federation on 10-June-1992

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A decree of the President of Russia on social and economic development of the Republic of Kabardino-Balkaria was issued [on (date????)] in which considerable attention was paid to the development of the hydroelectric energy sector and most of all to the construction of the Aushigerskaya Hydroelectric Plant According to the Presidential Decree the Nizhne-Tckerkesskiy cascade of the hydroelectric plants should become fully operational in the years 1997 to 1999 The Aushigerskaya Plant should be the first plant to be put into service followed by the Sovietskaya Hydroelectric Plant located 10 km upstream of Aushigerskaya

5 2 1 3 **Technical Aspects** Together with the planned Sovietskaya Hydroelectric Plant, the Aushigerskaya Plant will use the fall in the River Tcherek in the section between the place of confluence of the Tcherek-Balkazsky River and Tcherek-Bezengiyskyt Rivers and the settlement of Aushiger The Aushigerskaya Plant has a design capacity of 57 MW under normal operating head of 89 4 meters The reservoir area will be approximately 1 17 km^2 with an active storage volume of 0 22 million m^3

The Stage 1 Report (**Appendix A**) presents a detailed summary of the technical aspects (energy indicators and equipment data) of the Aushigerskaya Plant

5 2 1 4 **Environmental Aspects** There are no current environmental objections against the construction of the Aushigerskaya Plant

5 2 1 5 **Transmission Lines** As designed, the power from the Aushigerskaya Plant will be transmitted by six power lines of 110 kV two of them to the downstream Sovietskaya Plant and four to other nearby substations A total of (????) km of 110 kV lines are required The construction of these lines has not yet begun

5 2 1 6 **Economics** The shares of capital investment in the construction of the Aushigerskaya Hydroelectric Plant are estimated at $1,807/kW or $0 44/kWh (1991) The internal rate of return (IRR) of the Aushigerskaya Hydroelectric Plant, according to the amended design, 27% When determining this IRR, it was assumed that a JSC would be formed for the construction and operation of Aushigerskaya Plant It was taken into account that the electricity would be sold at whole scale prices on the plant's transmission lines The energy will be bought by the JSC "Kabbalkenergo" that supplies energy for the territory of the Republic of Kabardino-Balkaria

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The volume of capital investment to complete the construction is estimated at $103 million (1991) as shown in **Table 5 3** The design of the plant and estimated costs were updated in 1993 so the cost data are fairly reliable

Table 5 3 - Estimated Costs to Complete Construction of the Aushigerskava Plant

Item Number	Description	Estimated Cost $million (1991 US$)
1	Mobilization/Demobilization	3 1
2	Reservoir and Dams	5 1
3	Waterways	28 6
4	Powerplant (including Turbine Generator and other Mechanical Equipment)	48 2
5	Auxiliary Electrical System	1 5
	SUBTOTAL DIRECT COST	86 5
6	Contingency (Civil Electrical and Mechanical)	12 9
7	Administration Engineering and Construction Services	4 0
	TOTAL CONSTRUCTION COST	103 4

5 2 1 7 Construction Status As of Januarv 1994, excavations had already begun on diversion canal with about 5% of the work completed No other structural work had been started **Table 5 4** presents a summary of the construction scope of activities required to complete this plant

Table 5 4 - Scope of Woık to Complete Constructıon of the Aushıgerskaya Plant

Type of Work	Temporary Structures	Earth Dam	?????	Main Intake	Open Canal	Reservoir Area	Turbine/ Penstocks	Power house	Diversion Canal	Protection Dam	Total
Excavation of soft soil (thousands of m^3)			8 0	6 0	3300 0	941 0	119 0	154 0	1263 0		5791 0
Excavation of rock (thousands of m^3)					84 0						84 0
Filling with loamy soil (thousands of m^3)	10 6	4 0								268 0	282 6
Filling with gravel (thousands of m^3)		44 0	3 0	3 0	1841 0			6 0			1897 0
Filling with rock (thousands of m^3)	3 9										3 9
Drainage and filters (thousands of m^3)		5 0									5 0
Mass Concrete (thousands of m^3)			0 1	0 1	5 6	1 4	2 0	2 0			11 2
Reinforced Concrete (thousands of m^3)		1 0	8 0	3 0	65 0	24 0	19 0	18 0			138 0
Precast Concrete (thousands of m^3)			0 05								0 05
Site Grouting (thousands per m run)		0 8									0 8
Assembly of penstocks (thousands of tons)							2 0				2 0
Assembly of hydraulic and mech equipment (thousands of tons)			0 15	0 086		0 275		0 46			0 947

Table 5 4 - Scope of Work to Complete Construction of the Aushigerskaya Plant

Type of Work	Temporary Structures	Earth Dam	?????	Main Intake	Open Canal	Reservoir Area	Turbine/ Penstocks	Power house	Diversion Canal	Protection Dam	Total
Assembly of hydraulic power equipment (thousands tons)								0 82			0 82
Assembly of electric equipment (thousand tons)								0 33			0 38
Cofferdam Construction (thousands of m^3)	10 6										10 6

5 2 2 Zelentchukskava Plant

The Zelentchukskava Hvdroelectric Plants are located on the Kuban River in the [Karatchaevo-Tchergkessia **correct?**] Republic of the North Caucasus Region of Russia The project consists of two plants - the Zelentchukskava Plant and the Vezhne-Kzasnogorsk Plant - with a total design capacity of 262 MW and an average annual energy production of 0 769 billion kWh This project is designated as Priority No 2 for investment of the "plants currently under construction" for the following reasons

- a The Karatchaevo-Tchergkessia Republic has a current energy deficit
- b There is overwhelming political support for this project from both the Republic's government and the President of Russia
- c The plant is located near existing transmission line systems
- d The plants would supply potable water to the Republic's population and enterprises
- e The plants would provide some degree of flood control to protect the downstream inhabited areas from the destructive floods of the Bolshoi River and Maliy-Zelentchuk River Basins,
- f The estimated $203 7 million (1991) project costs are attractive for foreign investment, and
- g The project has an attractive rate of return for the required investment

<u>5 2 2 1 Owner/Operator</u> The Zelentchuk Hydroelectric Plants are owned by the JSC "Eec Poccuu Russia" The energy produced will be sold to the JSC "Kartcherenergo" for distribution within the Republic The current energy produced by the hydroelectric projects of the Kartcherenergo system satisfy about 5%of the Republic's needs The deficit energy is supplied by transferring power from JSC "Stavropolenergo"

<u>5 2 2 2 Political Aspects</u> The design of the Zelentchuk Hydroelectric Projects (the first phase) was made in consultation with GOSPLAN of the USSR (in an established order) by Letter No 2373-II of 23-December-1970 and approved by the Ministry of Fuels and Energy of the USSR (Resolution No 07-41 of 28-May-1971)

5 2 2 3 **Technical Aspects** The project includes the following aspects

a The Zelentchuk-Kuban canal,

b The Zelentchuk Hydroelectric Plant, and

c The Vezhne-Kzasnogorsk Hydroelectric Plant

The construction of the first phase of the Zelentchuk Hydroelectric Plants began according to the title given on the basis of the Decision No 940, 1975, of the Council of Ministers of the USSR

The Zelentchukskaya Plants have a combined design capacity of 262 MW under a maximum normal operating head of 240 meters The reservoir area will be approximately 2 45 km^2 with an active storage volume of 1 8 million m^3

5 2 2 4 **Environmental Aspects** Since its original design the Zelentchuk Hydroelectric Plants have been redesigned several times (most recently in 1991) as more emphasis was made on the protection of the environment The design modifications also reflected the concerns of the local population to protect the nearby health resorts of Teberdi, Dombai, Arhiza and reserves and national parks of Stavropol and Karatchaevo-Tcherkessia regions

5 2 2 5 **Transmission Lines** The project is located near existing transmission lines **[EPT to verify???]**

5 2 2 6 **Economics** The original estimated cost of the Zelentchuk plants is $304 5 million (1991) as shown in **Table 5 5** This corresponds to an investment share of the construction at $1162/kW or $0 40/kWh The expenses already made amount to $385/kW or $0 13/kWh (1991) Therefore the estimated remaining construction costs of the Zelentchukskaya Plants is $203 7 million (1991) or $778/kW and $0 26/kWh

5 2 2 7 **Construction Status** The costs incurred through January 1994 are shown on **Table 5 5** In general construction is approximately 35% complete

Table 5 5 - Estimated Costs to Complete Construction of the Zelentchukskava Plants

Item Number	Description	COSTS - US$ Million (1991)		
		Estimated	As of Jan-94	Remaining
1	Mobilization/Demobilization	23 1	4 9	18 20
2	Reservoir and Dams	36 7	9 4	27 30
3	Waterways	48 9	41 1	7 80
4	Powerplant (including Turbine, Generator and other Mechanical Equipment)	132 7	35 4	97 30
5	Auxiliary Electrical System	15 6	3 4	12 20
	SUBTOTAL DIRECT COST	257 0	94 2	162 80
6	Contingency (Civil, Electrical, and Mechanical)	32 1	0 7	31 40
7	Administration, Engineering and Construction Services	15 4	5 9	9 50
	TOTAL CONSTRUCTION COST	304 5	100 8	203 70

5 2 3 Zaramagskava Plant

The Zaramagskaya Hydroelectric Plant is located on the River Ardon in the territory of the Republic of Severnaya (North) Osetia of the North Caucasus Region of Russia The plant has a total design capacity of 342 MW and an average annual energy production of 0 789 billion kWh This project is designated as Priority No 3 for investment of the "plants currently under construction" for the following reasons

a The Severnaya (North) Osetia Republic has a current energy deficit
b There is political support for this project from both the Republic s government and the President of Russia,
c The plant is located near existing transmission line systems and
d The estimated $233 3 million (1991) project costs are attractive for foreign investment

<u>**5 2 3 1 Owner**</u> The Zaramagskaya Plant is owned by the JSC "EeC Poccuu" The energy produced will be sold to the JSC "Serkavkazenergo" for distribution within the Republic The current energy produced by the hydroelectric projects of the Seravkazenergo system satisfies about 20%of the Republic s needs The deficit energy is supplied by transferring power from JSC "Starzopolenergo"

<u>**5 2 3 2 Political Aspects**</u> The Ministry of Energy of the USSR ordered the design of the Zaramagskaya Plant 1 on the River Ardon in 1978

<u>**5 2 3 3 Technical Aspects**</u> The main design of the project before its approval was made in consultation with the interested institutions of the Republic of Severnaya Osetia

<u>**5 2 3 4 Environmental Aspects**</u> The original Zaramagskaya Plant design included a seasonably regulated reservoir In 1989, the State Committee on Environmental Control raised a question of terminating the construction of the Zaramagskaya Hydroelectric Plant 1 on the ground that the reservoir storage would destroy the deposits of carbonate mineral water in Tibsk and Zaramag Rivers Due to the fact that the question of continuing the construction of Zaramagskava Plant 1 is related mainly to the floods produced by a seasonably regulated reservoir some changes were made in the design in 1991 The amended design envisages no

seasonably regulated water storage

A commission expert on ecological analysis of the State Committee on Environmental Control of North Osetia gave its consent for the continuation of the project without a seasonably regulated water storage and with a dam up to 15-meter high

5 2 3 5 Transmission Lines The power of the hydroelectric plants will be transmitted by two single-circuit power transmission lines to a remote substation near Umal settlement and further into the energy system by power transmission lines of 330 kV "Umal-Tchezmen"

5 2 3 6 Economics The estimated cost to complete the Zaramagskaya Plant is $233 3 million (1991) This corresponds to $250/kw for the 400 MW of remaining capacity to be installed

5 2 3 7 Construction Status The Zaramagskaya Hydroelectric Plant 1 has been under construction since 1976 As of January 1994, approximately 20% of the construction work has been completed

5 2 4 Zagorskava (Stage 1) Pumped Storage Plant

The Zagorskava Hydroelectric Pumped-Storage Power Plant is located in the Central Region near the Town of Sergiev Posad (formerly Zagorsk) about 67 km from Moscow at the River Kunya This plant is the first pumped-storage plant in the Russian Federation

The current plant is the first stage of a planned two-stage construction project While the construction of Stage 1 approaches completion, Stage 2 can begin immediately if funding is available Stage 1 construction labor and equipment can be used for Stage 2 if there is no delay of work between the stages

<u>5 2 4 1 Owner/Operator</u> The Zagorskaya Plant is owned and operated by the JSC "Mosenergo"

<u>5 2 4 2 Political Aspects</u> The Zagorskaya Plant has been designed to take up peak loads of the power demand cycle, to serve as a quick-activation load and emergency standby generation source, and to take part in regulating system voltage

<u>5 2 4 3 Technical Aspects</u> The existing Stage 1 project consists of an upper reservoir formed by a ring embankment dam, a lower reservoir formed by a dam on the Kunya River, 500 kV switchyard, and upper reservoir intake structure The Stage 1 powerhouse includes six 200 MW units (Francis Pump/Turbines) Four units (800 MW) are currently operational Fianancing is required to bring on-line the remaining two units (400 MW)

The 7 5-meter diameter penstock consists of eighteen 40-meter long major segments connecting the upper reservoir intake structure and the lower reservoir powerhouse The penstock is steel-lined (10 mm) reinforced concrete (40 cm) Each 40-meter long major segment is constructed with ten 4-meter long pieces welded together Expansion joints are used between 40 meter major segment

<u>5 2 4 4 Environmental Aspects</u> There are currently no environmental problems associated with either the design or construction of the Zagorskava Plant

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5 2 4 5 Transmission Lines The transmission lines for the Stage 1 plant are now complete

5 2 4 6 Economics It is estimated that $100 million is required to complete construction of the Stage 1 plant

5 2 4 7 Construction Status Four 200 MW units are currently in normal operation, Unit 5 is used as a synchronous condenser to stabilize system voltage since the power penstock is not yet complete (about 50%) Unit 6 mechanical and electrical equipment is in final assembly - the penstock has not yet been started

5 2 5 Bogutchanskaya Plant

The Bogutchanskaya Hydroelectric Plant is located on the River Angara in the Krasnoyarsky Region of Siberia This plant represents the fourth stage of the Angarsky cascade of hydroelectric plants (after Irkutskaya, Bratskaya, and Ust-Ilimskaya plants) The plant has an initial design capacity of 3000 MW and an average annual energy production of 17 6 billion kWh, the project has been designed to allow expansion to 4000 MW and 17 8 billion kWh This project is designated as a priority for investment under the category of "plants currently under construction" for the following reasons

a The construction of Bogutchanskaya plant is important for the energy system of Russia as well as for a social and economic development of the Nizhnee-Priangarie (Downstream Angara) region rich in natural resources

5 2 5 1 Owners In (?????), the State Committee of the Russian Federation for the Management of State Property gave its permission to the production association "Bogutchangesstroy" to be transformed into an open joint-stock company (OJSC) on the condition it hands 49% of the stocks of its statutory capital over to the statutory fund of the Russian Joint-Stock Company of Energy and Electrification "Yedinaya Energosystema Rossii" (Unified Power System of Russia)

By a decision of the Regional Committee for Management of State Property the state enterprise "Bogutchangesstroy" was transformed into an OJSC with statutory capital of 1,475,288,000 Roubles and registered by the Kezhemsky District Administration, Krasnoyarsky Region of Siberia The permission for registration and initial issuance of stocks of the OJSC "Bogutchangesstroy" was confirmed by the Territorial Department of the State Committee on Antimonopoly Policy and Support for New Economic Structures

The regional Administration executed a state registration of the issued stocks and on the 5th of November of 1993 included them in the roster of securities

5 2 5 2 Political Aspects The construction of the plant began by an order n798-p of 30-April-1980 of the Council of Ministers of the USSR

5 2 5 3 Technical Aspects The project's turbines are Francis type with a rated capacity of 340 MW the diameter of the runner is (?????) and the speed of rotation is 90 9 RPM The maximum head is 69 3 meters The units are designed top operate at an initial head of 40 meters to allow energy production at an intermediate construction level The first stage project will have a total of 9 units with a combined gross generation capacity of 3000 MW The expanded project will have a total up to 12 units with a gross generation capacity of 4000 MW The generators have an air cooling system and a rated capacity of 333 MW/370 MW The rated voltage is 15 75 kV

Depending on the level of financing available, there are three basic alternatives for commissioning the first-stage units as shown on **Table 5 6**

Table 5 6

Alternative Time Table of Making the Bogutchanskaya Plant Fully Operational

Scenario Number	Years of Commissioning Units		
	First Units Commissioned	Making the Plant Fully Operational	The Sequence of Commissioning Units by Years
1	1998	2001	2+3+3+1
2	2000	2002	2+3+3+1
3	2002	2005	2+3+3+1

The Bogutchanskaya Plant has been designed to begin generating revenue as soon as possible Several of the units will be commissioned at an intermediate water level mark in the reservoir of 178 meters under a minimal operating head of 40 meters The Bogutchanskaya reservoir will be gradually filled with water as the civil structures continue to be raised during construction and the reservoir area becomes ready This readiness is determined, on one hand, by the level of readiness of the installations of the head front, and, on the other, by the fact that the reservoir can be filled with water only when there is no navigation since the River Angara is the exclusive provider of the minimal navigational depths of the River Enisei

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5 2 5 4 Environmental Aspects There are currently no environmental objections to either the design or construction of the Bogutchanskaya Plant

5 2 5 5 Transmission Lines The Bogutchanskaya Plant is being constructed within the Krasnoyarskaya Energosystema (energy system) which is part of the Unified Energy System of Siberia (UESS) The latter is composed of 10 smaller energy systems (ES) from the Omskava ES in the west to the Tchitinskay ES in the East The possibilities of using the output of the Bogutchanskaya plant within the UESS are determined by the three major factors

a The forecast of the energy consumption in the UESS,
b The schedule of making the units operational at the Berezovskaya local fuel plant-1 and
c The schedule of making operational the Bogutchanskaya plant units

It should be noted though that with all the different combinations of the three aforementioned factors there is a certain possibility of transmitting the excess energy produced by the Bogutchanskaya plant in the UESS to the European Energy System (EES) or to China

5 2 5 5a Transmission to the European Energy System Due to a limited transmission capacity of the Transmission Power Line (TPL) it was possible to transmit in 1993 from the UESS to the EES two to three billions of kWh (actual consumption of energy by the UESS was 0 6 billion kWh) An upgraded transmission capacity of the TPL Siberia-Kazakhstan-Urals to the EES would make it possible to transmit 9 0 billion kWh of energy and 2 to 2 5 million kW of capacity by the year 2000 The pattern of connecting the Bogutchanskaya plant to the EES is the same in all forms of energy usage in the specific areas (**Table 5 7**)

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Table 5 7 - Transmission Lines Required for the Bogutchanskava Plant

Power installations to be constructed	Performance Data
a 500 kV Bogutchanskaya-Kansk high-voltage line (2 networks)	900 km (2 x 450 km)
b 1150 kV Itat-Kansk high voltage line (with a substation of 1150 kV at Kansk)	550km
Total Distance	1450km

As far as the 500 kV Bogutchanskaya-Kansk high voltage line (HVL) is concerned, a feasibility study has been made and approved and work drawings have been provided for possible beginning of the construction A feasibility study has been made and approved for the Itat-Kansk HVL of 1150 kV but no drawings have been done A construction of a single HVL of 500 kV up to the city of Kansk would not allow the city to receive the energy output of the Bogutchanskaya plant because it would lead only to the Kransnoyarskaya energy system which has an excess of energy That's why a construction of an Itat-Kansk HVL of 1150 kV is needed

In order to be able to transmit the output of the Bogutchanskaya plant to the European part of Russia the construction of the Itat-Barnaul-Ekibastuz-Koktchetav-Kustanai-Tcheliabinsk HVL of 1150 kV must be completed The work that has to be done includes a completion of the construction of the Itat-Barnaul HVL of 1150 kV, construction of a substation of 1150 kV in Tcheliabinsk, installation of equalizers at substations and adjustment of the whole HVL for the design voltage

5 2 5 5b Transmission to China The energy output of the Bogutchanskava Plant can be transmitted to China in two directions Alternative number one (Eastward) the distance from the Bogutchanskaya plant to the Russian border is about 3000 km The capacity to be transmitted is of 1200 MW and the energy should be transported through Irkutskava, Buriatskaya and Tchitinskaya energy systems

Alternative number two (Westward) the distance from the Bogutchanskaya Plant to the border of Russia is 1500 km The energy should be transmitted through the networks of the

Krasnoyarsky Khakassky and Altaisky regions

In all alternatives of energy transmission there is a need to have a 500 kV HVL of alternating current with a possibility of installing some sections of direct current at the border with China

5 2 5 6 Economics It is estimated that $1 4 billion (1991) are required to complete the construction of the Bogutchanskaya Plant This is based on the 01-January-1994 level of completion as shown in **Table 5 8**

Table 5 8
Completion Level of Construction of the Bogutchanskaya Plant as of 01-Jan-94

	Estimated Construction Cost (1991 US$ = Rouble)			Percent of Total		
Indicators	Estimated Costs	Completed	To be Completed	Estimated Costs	Completed	To be Completed
Total Construction	2601	1231	1370	100	47 3	52 7
BREAKDOWN						
Production facilities	1637	795	842	100	48 6	51 4
Settlement	355	206	149	100	58 0	42 0
Reservoir	609	230	379	100	37 8	62 2

5 2 5 7 Construction Status The construction status of the Bogutchanskaya Plant as of 01-January-1994 is as follows

a The Angara river has been dammed

b The industrial installations for producing a concrete mix grading gravel to size producing an asphalt and concrete mix and crushed stone have been constructed

c Almost all production bases needed for a timely commission of units have been constructed,

d The transport infrastructure has been built and become operational,

e The city of Kodinsk has been built for 16 thousand inhabitants and has a secured supply of energy, water and heat,

f A forest survey in the reservoir zone is 80% complete,

g A concrete dam along the whole head line, mainly at 161 m mark, has been built, 60% of concrete has been placed at the installations needed for the operation of the plant and

h The construction of a rock-filled dam has begun

The data on the volume of work done in the construction of the main installations of the Bogutchanskaya plant is shown on **Table 5 9**

Table 5 9
Construction Status of the Main Installations of the Bogutchanskava Plant

Type of Work	Measure Unit	Scope of Work			Completed as of 01 Jan 1994 %
		Total	Completion as of 01 Jan 1994	To Be Completed	
Excavation/sorting of soft soils	Millions of m^3	3 952	3 835	0 117	97 0
Excavation/sorting of rocks	Millions of m^3	3 862	3 721	0 141	96 3
Excavation of rocks	Millions of m^3	0 017	0 012	0 005	70 6
Filling with soft soils	Millions of m^3	4 621	3 425	1 196	74 1
Filling with rocks	Millions of m^3	24 954	8 098	16 856	32 4
Concrete and reinforced concrete including	Millions of m^3				
underground		2 315	0 947	1 36	40 9
asphalt and concrete mix		0 139	0 015	0 12	10 8
Grouting	Thousands per meter run	113 460	30 672	82 78	27 0
Drainage wells	Thousands per meter run	18 539	4 622	13 91	24 9
Metal Structures and devices	Thousands tons	33 411	6 953	26 45	20 8
Assembly of the hydraulic power equipment	Thousands Tons	29 007		29 00	0
Assembly of Electrical and technical equipment	Thousands tons	10 000		10 0	0

5 2 6 Burevskaya Plant

There is a acute need of electric energy in the Far East energy system of the Russian Federation However the Bureyskaya Hydroelectric Plant's construction has been contained by the lack of financing

<u>5 2 6 1 Owners</u> The State Committee of the Russian Federation on the Management of State property gave permission to the "Zeyagesstroy" production association to transform it into an open joint-stock company on the condition it gives 49% of its authorized capital to the registered fund of the Russian Joint-Stock Company on Energy and Electrification "Yedinaya Energosystema Rossii" (Unified Energy System of Russia)

By a decision of the Regional Committee on State Property Management the state enterprise Zeyagesstroy" was transformed into a JSC and registered as such by the Amurskiy region Administration

<u>5 2 6 2 Political Aspects</u> The Bureyskaya integrated hydraulic scheme on the River Bureya is supposed to supply energy for the developing industrial region of the Far East composed of the Amurskaya province, Khabarovskiy and Primorskiy region and South Yakutiya as well as to control floods in the water-meadow of the River Bureya and in the middle stream of the River Amur

<u>5 2 6 3 Technical Aspects</u> The main structures of the Bureyskaya plant include

a Gravitation cement dam,
b Powerhouse adjacent to the dam, and
c Surface notches combined in with the dam and equipped with flat wheel gates

The total length of the dam along the crown in 765 meters and the maximum height is 139 meters Along its length the dam is divided into the following parts

a Right-bank part 244-meter long,
b Powerhouse part 180-meter long, and
c Left-bank blank part 197-meter long

The plant s scheme includes

a	Powerhouse with an assembly site and a transter cargo site
b	Open distribution devices (ODD) of 500 kV and 220 kV
c	Cable tunnel and a shaft that connect the control room with the ODD to 500 kV and 220 kV and
d	Powerhouse area with breast-walls

The powerhouse has six blocks according to the number of units that have to be assembled in the plant The basic energy data for the Burevskaya Plant are shown in the **Table 5 10**

Table 5 10 - Basic Energy Data for the Bureyskaya Plant

Indicators	Factors
Design capacity, MW	2000
Number of units and capacity of each unit	6 x 333
Average Multiyear Energy Output, billion kWh	7 1
Design head, meters	103

The design solutions and the layout of the Bureyskaya plant main structures allow a commissioning of the first two units with a lower than the design head using changeable runners in order to replace temporary runners with permanent ones If financing becomes available the commissioning of the first unit is planned for the beginning of November of 1998

To secure the timely commissioning of the first unit in 1998 in the event of an insufficient water inflow (95% of water supply) it is necessary to begin to fill the reservoir in May of 1998

The draw-downs during the navigational period (from May through October) have to be not less than 600 m^3/s , the draw-downs should be limited by the flow rate of influx only in the event the latter is less than 600 m^3/sec During winter-time (from November through April) the sanitary draw-down to the downstream wall should not be less than 100 m/sec

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The separable runners of the first two units are to be replaced with permanent ones in June and August of 2002 when the head front is completely secured The time-table of commissioning the Bureyskaya plant units is shown in the **Table 5 11**

Table 5 11 - Time Table of Commissioning of the Bureyskaya Plant Units

Years	Unit Number					
	1	2	3	4	5	6
1998	November*					
1999		August*				
2000						
2001			July	November		
2002	June**	August**			January	May

* - Commissioning of units number 1 and 2 with Separable Runners,
** - Replacement of the separable runners of the units member 1 and 2 by the standard one

The Bureyskaya Plant design includes six radial-axial turbines of PO140/846 type with a runner diameter of 6 15 meters which each have a capacity of 342 MW at a design head of 103 meters and a rotation frequency of 125 RPM The turbines are designed for operation at heads of 97 5 up to 122 meters

The hydro turbine is connected to the three-phase generator CB-1315/255-4/2 of an umbrella type which has a rated capacity of 372 2/335 MVA/MW, a voltage of 15 75 kV and a rotation frequency of 125 RPM with a static thyristor excitation system

<u>**5 2 6 4 Environmental Aspects**</u> The environmental aspects of the Bureyskaya Plant are unknown at this time

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5 2 6 5 Transmission Lines The output of the Bureyskaya Plant will be transmitted to the Far East Unified Energy System (FEUES) For this to occur it will be necessary to

a To build a high-power line (HPL) of 220 kV from the Bureyskaya Plant to the Zavitinskaya Substation

b To rehabilitate Zavitinskaya Substation of 220 kV and install two transformers

c To connect "Svobodiy-Khabarovsk" HPL of 500 kV to Bureyskaya Plant and

d To build Bureyskaya Plant - Komsomolsk HPL of 500 kV (through Urgal - Start) - during the first stage it is recommended to use this HPL at 220 kV

The capacity output circuit design envisages connecting Svobodniy-Khabarovsk HPL of 500 kV to the wires of the ODD of 500 kV the third HPL of 500 kV with the destination to Komsomolsk Substation and a projected fourth HPL of 500 kV The ODD of 220 kV is to be connected to two-circuit HPL of 220 kV wired to Zvitinskaya Substation in order to supply energy for the construction of the hydroelectric scheme and also connected temporarily to the 220 kV wires of Urgal-Start HPL of 220 kV

Table 5 12 shows the electric network that has to be built to transmit the output of Bureyskaya Plant

Table 5 12 - Required Electric Network Structures

Structure s Name	Length of HPLs km Substations Capacity MWA
1 Zavitinskaya-Bureyskaya 220 kV Substation	2 x 79 km
2 Zavitinskaya Substation	2 x 25 MWA
3 Connections of Svobodiy-Khabarovskaya Substation 500 kV HPL at Bureyskaya Plant	60 + 60 km
4 Bureyskaya Plant-Komsomolsk 500 kV HPL	780 km

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At the Bureyskaya Plant the generators are to be divided among the wires of 220 kV and 500 kV transmission lines as follows

a 2 Generators for wires of 220 kV

b 4 Generators for wires of 500 kV

There is a study under way of the possibility of transmitting a considerable part of Bureyskaya Plant output to China No feasibility study for route selection or the voltage of the HPL has been done yet

5 2 6 6 Economics **Table 5 13** shows the cost data which illustrates the level of completion of the Bureyskaya Plant construction as of 01-January-1994

Table 5 13
Analysis of Completion of the Bureyskaya Plant Construction as of 01-Jan-1994

Construction Cost Estimate	Total		Completed as of 01-Jan-1994		Remaining	
	$million (1991)	%	$million (1991)	%	$million (1991)	%
Total Project	2,776	100	588	21 2	2,188	78 8
BREAKDOWN						
- industrial objects	2,142	100	495	23 1	1 647	76 9
- housing and civil structures	321	100	45	14 0	276	86 0
- reservoir	213	100	48	22 5	165	77 5

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Table 5 14 presents data on the level of completion of the Burevskava Plant s main structures

Table 5 14
Construction Status of the Burevskava Plant Main Structures as of 01-Jan-1994

Construction Cost Estimate	Total		Completed as of 01-Jan-1994		Remaining	
	$million (1991)	%	$million (1991)	%	$million (1991)	%
Total, Main Structures	683 5	100	99 6	14 6	583 9	85 4
BREAKDOWN						
- Dam	384 4	100	62 1	16 2	322 3	83 8
- Plant Scheme	258 1	100	12 4	4 8	245 7	95 2
- Cofferdams (and removal)	17 9	100	16 7	93 3	1 2	6 7
- Auxiliary Structures	23 1	100	8 4	36 4	14 7	63 6

5 2 6 7 Construction Status The construction of Bureyskaya Plant began in 1976 As of 01-January-1994, that is during 17 years, out of the total estimate cost, only $543 million (1991) have been spent, including $433 million for construction and assembly works, that is 22 1% and 23 3% out of total budget estimate costs approved by the order N5917C of the Ministry of Fuel and Energy of 11-December-1991

As of 01-January-1994 out of the amount of investments assigned for a permanent settlement together with social and cultural structures (section B of the combined estimates) only $45 0 million (1991) were spent or 14% of amount approved in the aforementioned order

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5 3 Assessment of New Plants to Start Construction

Many hydroelectric power plants are currently under design in the Russian Federation where no construction has started The Project Team has identified three priority plants for for investment in the period 1995 to 2001 In selecting these plants the Project Team considered political technical environmental transmission lines and economical factors for each project

The three priority plants currently under design which have been identified for investment include the Zagorskaya Pumped-Storage Plant - Stage 2 (800 MW) in the Center Region the Ziuratkulskaya Plant (10 4 MW) in the Urals Region, and the Pravdinskaya Plant (12 7 MW) in the Northwest Region **Table 5 15** shows the project characterisitcs of these three priority plants **Table 5 16** shows the investment requirements for construction of these plants The following sections discuss the characteristics of each of these plants

Table 5 15 - Priority New Plants to Start Construction Characteristics

Plant Name	Region	Capacity (MW)		Output (Billion kW-hr)	
		Before Rehab	After Rehab	Before Rehab	After Rehab
Zagorskaya PS 2	Center	0	800	0	800
Ziuratkulskaya	Urals	0	10 4	0	030
Pravdinskaya	Northwest	0	12 7	0	030
TOTALS		0	823 1	0	860

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Table 5 16 - Prioritv New Plants to Start Construction Investment Plan

Plant Name	Investment Requirement Billion $ (1991 US$=1Rb)							
	1995	1996	1997	1998	1999	2000	2001	Total
Zagorskaya PS - 2								
Cash Flow %	10%	15%	15%	15%	15%	15%	15%	100%
Cash Flow billion US$	057	0855	0855	0855	0855	0855	0855	0 570
Plant Capacity MW	0	0	0	200	400	600	800	800
Ziuratkulskaya								
Cash Flow %	20%	50%	30%	-		-	--	100%
Cash Flow billion US$	0030	0075	0045					0 015
Plant Capacitv MW	0	0	10 4	10 4	10 4	10 4	10 4	10 4
Pravdinskaya								
Cash Flow %	20%	50%	30%	--	-	--	-	100%
Cash Flow billion US$	007	0175	0105					0 035
Plant Capacity MW	0	0	12 7	12 7	12 7	12 7	12 7	12 7
TOTALS								
Cash Flow %	11%	17%	16%	14%	14%	14%	14%	100%
Cash Flow billion US$	067	1105	1005	0855	0855	0855	0855	0 620
Plant Capacity MW	0	0	23 1	223 1	423 1	623 1	823 1	823 1

5 3 1 Zagorskava (Stage 2) Pumped-Storage Plant

The Zagorskaya Hydroelectric Pumped-Storage Plant is located some 80 km from Moscow The Plant regulates generation capacity at peak hours and falls of electricity loads at "Mosenergo" and other energy systems of the central regions of Russia The Stage 1 construction of 1200 MW is near completion As of 1994 four out of six units are in service

There are a series of conditions favorable for an expansion of the Zagorskaya Hydroelectric Storage Plant including the availability of trained construction workers with normal living conditions, the existence of a production base and a minimum requirement of additional land The most appealing aspect of this project is that the construction labor force (including the Town of Bogorodskaye), production facilities, and heavy equipment are already in place due to the ongoing Stage 1 construction The presence of these factors greatly reduces the mobilization cost for Stage 2

For the Stage 2 construction 338 hectare of land are needed including 100 hectare for temporarily stripping Out of total allocated land are 16 hectare are arable land and 288 hectare are woods

5 3 1 1 Owner/Operator The Zagorskaya Plant is owned and operated by the JSC "EeC Poccuu" Energy is sold to the JSC "Mosenergo" for distribution

5 3 1 2 Political Aspects The feasibility study for the Zagorskava Plant was analyzed according to a standard procedure and the City Soviet of People s Deputies of Seguiev- Posad by it decision No 68/10 of 16-July-1992 found it advisable to make a full scale design for Stage 2

5 3 1 3 Technical Aspects The basic energy and equipment characteristics of the Zagorskava Hydroelectric Storage Plant (Stage 2) are shown in the Stage 1 Report (**Attachment A**) The scope of work required to complete Stage 2 is shown on **Table 5 17**

For the second stage of the Zagorskaya Hydroelectric Storage Plant an upper storage reservoir would be constructed adjacent to the existing reservoir on its southern part with a common part of the dam that divides both water storages Separate intake and powerhouse structures would be constructed Both hydroelectric plants share the lower reservoir which has already been designed to accomodate the Stage 2 water

The existing Stage 1 construction base is used for constructing Stage 2 It is planned to begin the work on basic structures during the first year with pit excavation for the Stage 2 powerhouse excavations for penstocks building of the dam of the upper reservoir and excavation of soil for a water intake structure At the end of the first construction year the fill of a cofferdam that limits that plant's pit will begin A pit for barges is under construction at the lower reservoir

During the second construction year it is planned to finish the fill of the plant's pit cofferdam and begin anchoring the lower reservoir with rocks that will be brought by dump-trucks and barges

During the their and the fourth years all the Stage 2 structures will be completed

At the end of the fifth year the commissioning of the first unit is planned

The works on the upper reservoir are due to finalize by the middle of the sixth year before commissioning of the second unit The cement placing for the next units of the plant will be done in accordance with the time table of the units supply for assembly and installation of hydraulic power equipment

5 3 1 4 Environmental Aspects Currently the feasibility study is on an expert evaluation in the State Environmental Expertise body of the Ministry of Nature of Russia

5 3 1 5 Transmission Lines For the transmission of power produced by the Zagorskaya Hydroelectric Storage Plant 2 it is envisioned to build an additional transmission power line of 500 kV

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Table 5 17 - Scope of Work for the Construction of Zagorskaya Pumped-Storage Plant- (Stage 2)

Type of Work	Plant's Scheme	Head Penstocks	Water-Intake Structure	Upper Reservoir	Lower Reservoir	Derivation Canal	Land Cofferdam	Tot l
1 Excavation TOTAL	4627 7	1363 4	216 9	820 0		1048 5		8176 5
including								
grass soil	55 1	26 2	15 0	820 0				916 3
loamy soils	3734 1	1337 2	201 9			1048 5		6421 7
- sand and gravel	838 5							838 5
2 Earthfill TOTAL	3 45	1 17		10700 0		117 0	258 3	11079 9
including								
- loamy soils				9040 0		117 0		9157 0
- sand and gravel				1600 0			124 3	1724 3
(????????)							134 0	134 0
- (?????????)	3 45	1 17		60 00				64 62
3 Grass Soil TOTAL	792 2	86 0	156 0					1034 2
including								
- loamy soils	342 2		156 0					498 2
- sand and gravel	450 0	86 0						536 0
4 Drainages filters and anchoring TOTAL	162 7	3 0	2 0	480 0	308 31	46 85		1026 66
including								
- sand and gravel				200 0	21 86			221 86
(???????????)	110 0	3 0	2 0	15 0				120 0
- rock cast				265 0	286 45	46 85		598 1
5 Cofferdam Removal							258 3	258 3

NOTE The scope of work presented in **Table 5 ??** above is valid for the Stage 2 powerhouse constructed in an open pit and the upper reservoir dam would be constructed of free-flowing bulk soils with the upper slopes anchored with rocks

5 3 1 6 Economics The results of a feasibility study show that the construction of the Zagorskava Hydroelectric Storage Plant is the most efficient way of solving the problem of irregular loads for "Mosenergo" energy system The recoupment period of additional investments compared to the construction of alternative steam and gas plants is from 6 to 8 years

The construction cost of the Zagorskava Hydroelectric Storage Plant (Stage 2) are estimated at $570 million (1991) as shown on **Table 5 18** The investment shares of the construction of Zagoskava Hydroelectric Storage Plant 2 are estimated at $713 /kW (1991)

Table 5 18 - Estimated Construction Cost for the Zagorskava-2 Plant

Number	Description	Estimated Cost $million (1991)
1	Mobilization/Demobilization	9 1
2	Reservoir and Dams	147 6
3	Waterways	71 3
4	Powerplant	107 8
5	Turbine/Generator	86 3
6	Auxiliary Electrical System	41 9
7	Miscellaneous Mechanical Equipment	5 3
	SUBTOTAL DIRECT COST	469 3
8	Contingency, Civil, Electrical, and Mechanical	89 5
9	Administration and Engineering and Construction Services	11 2
	TOTAL CONSTRUCTION COST	570 0

5 3 2 Ziuratkulskaya Plant

The Ziuratkulskaya Hydroelectric Plants N1 and N2 were constructed in 1942-1951 They are located in the Satkinsk district of the Cheliabinsk region on the river Bolshaya Satka In 1978 the Ministry of Energy decided to take the plants out of operation and the equipment was dismantled It is proposed to reactiviate these plants with modern equipment and controls

__5 3 2 1 Owner/Operator__ The Ziuratkulskaya Plant is owned and operated by the JSC "EeC Poccuu" Energy is sold to the JSC "Tcheliabenergo" for distribution

__5 3 2 2 Political Aspects__ In 1993, the Russian Federation made a feasibility study for investments with the purpose of rehabilitating the Ziuratkulskaya Hydroelectric Plants A single phase scheme of rehabilitation was recommended

The energy of the Ziuratkulskaya Hydroelectric Plant will be used by JSC "Tcheliabenergo" During the last 5 years the Tcheliabinsk Power System has deficit of capacity and power as well The system is located at the end of the General Power System of the region of Urals and insufficient line (from the point of view of transmission capacity) with the neighboring power systems, which are redundant, mainly with those of the JSCs Sverdlovsk and Bazhkiz As a result, there have been certain periods when the "Tcheliabenergo" had to cut power used by consumers

__5 3 2 3 Technical Aspects__ The main energy and equipment characteristics of the Ziuratkulskaya Hydroelectric Plant are shown in the Stage 1 Report (**Attachment A**)

Due to the fact that the plant site has been already developed the scope of work for reviving this plant is relatively small as shown on **Table 5 19** The existing road network allows simultaneously access to all parts of the construction site allowing equipment to be easily moved from one place to another Since all essential construction work can be executed during one warm season, there will be no need to build auxiliary facilities The precast concrete, metal-work and basic equipment can be assembled practically upon delivery

Table 5 19 - Scope of Work for Rehabilitating the Ziuratkulskava Plant

Type of Work	Measurement Unit	Quantity
1 Wood-cutting/Clearing	Hectare	9 84
2 Soil excavation including		
soft soil	m	23020 0
rock	m	4300 0
3 Fill including		
soft soil	m^3	52400 0
rock	m^3	4120 0
4 Fill of penstock	m^3	14200 0
5 Solid reinforced concrete	m	746 0
6 Precast reinforced concrete	m	172 6
7 Finishing works	m^3	1400 0
8 Territory layout	m	42150 0
9 Metalwork	Ton	881 6
10 Reservoir	m	1000 0
11 Demolition brick and cement structures	m^3	1104 0
12 Rebar steel	Ton	10 0
13 Road work (covering sites and roads with asphalt)	m	10530 0
14 Fixing of sloops with anchoring rock	m	430 0
15 Disassembly of metal works	Ton	25 0
16 Stamp removal	m	460 0
17 Anchoring slopes with grass	m	9500 0
18 Assembly of mechanical equipment	Ton	48 7
19 Assembly of hydraulic power equipment	Ton	133 3

The rehabilitation work should begin in January with wood-cutting to clear the open flow canal zone During a warm period the basic works begin that is excavation of soil and rock cement placing and assembly in all structures The rest of work has to be done before winter time and the basic equipment has to be assembled by the year end

5 3 2 4 Environmental Aspects The rehabilitation of the Ziuratkulskaya Hydroelectric Plant will increase the recreational value of the surrounding territory which is an important factor because it is a rest area with many valuable places and is one of the least polluted places in the region The rehabilitation of the Ziuratkulskaya Hydroelectric Plants will not change the parameters of the Ziuratulsky reservoir and thus will not effect the ecology

5 3 2 5 Transmission Lines The output of the Ziuratkulskaya Hydroelectric plant is transmitted by the existing power transmission line of 35 kV "Satka-Tiaga-Zivratkul"

5 3 2 6 Economics The estimated construction costs is $15 million (1991) The internal rate of return that determines the efficiency of the investments needed for rehabilitating the Ziuratkulskaya Hydroelectric Plant is estimated at 10 6%

5 3 3 Pravdinskava Plant

The Pravdinskava Hydroelectric Plant 3 was built in 1922-1925 and is located in Kalimngrad region on the river Aalle It is not in service at the present time The feasibility study for a rehabilitation and reconstruction of the Pravdinskava Hydroelectric Plant 3 was made in 1989

5 3 3 1 Owner/Operator The Pravdinskaya Plant is owned and operated by the JSC "EeC Poccuu" Energy produced by the Pravdinskaya Hydroelectric Plant 3 is used by the JSC "Kalimngradenergo"

5 3 3 2 Political Aspects The Joint-Stock Company "Kalimingradenergo" on the territory of which Pravdinskaya Plant is located has found itself isolated from the other energy systems of Russia because after the disintegration of the former Soviet Union The Kaliningrad region has turned into a Russian enclave surrounded by foreign states The Pravdisnskava Plant rehabilitation is extremely important for securing a reliable energy supply independent of the neighboring states

5 3 3 3 Technical Aspects The main energy characteristics of the Pravdinskaya Hydroelectric Plant are shown in the Stage 1 Report (**Attachment A**)

5 3 3 4 Environmental Aspects

5 3 3 5 Transmission Lines

5 3 3 6 Economics The investment shares of the construction of the Pravidinskaya Hydroelectric Plant 3 are estimated at $2756 /kW (1991) The basic cost indicators for the Pravdinskaya Hydroelectric Plant 3 are shown in **Table 5 20**

Table 5 20 - Estimated Construction Cost for the Pravdinskaya Plant

Number	Description	Estimated Cost $million (1991)
1	Mobilization/Demobilization	0 1
2	Reservoir and Dams	4 8
3	Waterways	--
4	Powerplant	2 3
5	Turbine/Generator	17 4
6	Auxiliary Electrical System	1 4
7	Miscellaneous Mechanical Equipment	2 2
	SUBTOTAL DIRECT COST	28 2
8	Contingency, Civil, Electrical, and Mechanical	2 8
9	Administration and Engineering and Construction Services	0 5
	TOTAL CONSTRUCTION COST	31 5

5 4 Summary and Conclusion

The Project Team has identified six (6) priority new hydroelectric plants which are currently under construction for financial investment to complete construction in an expedited manner These six plants - Aushigerskaya Zelentchukskaya Zaramagskaya Zagorskaya-1 Bugutchanskaya, and Bureyskaya - require approximately $4 24 billion (1991) over the seven year period 1995 to 2001 These project will add 6,861 MW and 27 694 billion kWh of energy when completed In aggregate these projects will cost approximately $618/kW of generation capacity and $0 15 /kWh of energy produced

The Project Team has also identified three (3) new hydroelectric plants for financial investment to start construction These three plants - Zagorskaya-2, Ziuratkulskaya, and Pravdinskaya - require approximately $620 million (1991) over the sevn year period 1995 to 2001 Zagorskaya-2 is an expansion of Zagorskaya-1 Pumped-storage plant located near Moscow The other two projects are revitalizations of plants which had been abandoned previously because of poor equipment condition and efficiency, and the cost of replacement Revitalizing abandoned plants with new equipment and controls minimizes the evironmental concerns and reduces the overall construction costs The civil structures at both plant locations are reported to be in good condition

The completion of these nine new hydro plants will provide additonal capacity to the Russian Federation starting almost immediately with the completion of the Zagorskaya-1 Plant Large increases in capacity will be realized as the two projects east of the Urals come on line about 1998 to 2000 These new plants will increase the system's nameplate generation capacity by approximately 6884 MW (from 800 to 7684 MW) and average annual energy production by approximately 27 754 billion kWh (from 0 8 to 28 554 billion kWh) as shown in **Table 5 21** The total investment requirement for new plants is $4 86 billion over the period 1995 to 2001 as shown in **Table 5 22**

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Table 5 21 - Priority New Plant Construction Characteristics

Existing Plant	Plant Status[1]	Region	Generation Capacity (MW)		Avg Annual Energy (billion kWh)	
			Before Rehab	After Rehab	Before Rehab	After Rehab
Aushigerskava	3	North Caucasus	0	57	0	0 236
Zelentchukskava	3	North Caucasus	0	262	0	0 769
Zaramagskaya	3	North Caucasus	0	342	0	0 789
Zagorskava PS 1	3	Center	800	1200	0 800	1 200
Bogutchanskava	3	Siberia	0	3000	0	17 6
Bureyskaya	3	Far East	0	2000	0	7 1
Zagorskaya PS - 2	4	Center	0	800	0	800
Ziuratkulskaya	4	Urals	0	10 4	0	030
Pravdinskaya	4	Northwest	0	12 7	0	030
TOTALS			800	7684 1	0 800	28 554

Note Plant Status Definition

"3" = New plant currently under construction Investment required to complete ongoing construction

"4" = New Plant under design Investment required to start construction

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Table 5 22- Priority New Plant Construction Investment Plan

Plant Name	Investment Requirement Billion $ (1991 US$=1Rb)							
	1995	1996	1997	1998	1999	2000	2001	Total
Aushigerskaya								
Cash Flow %	20%	50%	30%	-		-	--	100%
Cash Flow billion US$	0206	0515	0309					0 103
Plant Capacity MW	0	0	57	57	57	57	57	57
Zelentchukskaya								
Cash Flow %	10%	20%	30%	30%	10%	--	-	100%
Cash Flow billion US$	0204	0408	0612	0612	0204			0 204
Plant Capacity MW	0	0	60	160	262	262	262	262
Zaramagskaya								
Cash Flow %	10%	20%	30%	30%	10%	-	-	100%
Cash Flow billion US$	0233	0466	0699	0699	0233			0 233
Plant Capacity MW	0	0	57	228	342	342	342	342
Zagorskaya PS - 1								
Cash Flow %	20%	50%	30%	-			--	100%
Cash Flow billion US$	020	050	030					100
Plant Capacity MW	800	1000	1200	1200	1200	1200	1200	1200
Bogutchanskaya								
Cash Flow %	10%	15%	15%	15%	15%	15%	15%	100%
Cash Flow billion US$	140	210	210	210	210	210	210	1 400
Plant Capacity MW	0	0	0	666	1666	2666	3000	3000
Bureyskaya								
Cash Flow %	10%	15%	15%	15%	15%	15%	15%	100%
Cash Flow billion US$	220	330	330	330	330	330	330	2 200
Plant Capacity MW	0	0	0	342	1026	1700	2000	2000
Zagorskaya PS - 2								
Cash Flow %	10%	15%	15%	15%	15%	15%	15%	100%
Cash Flow billion US$	057	0855	0855	0855	0855	0855	0855	0 570
Plant Capacity MW	0	0	0	200	400	600	800	800
Ziuratkulskaya								
Cash Flow %	20%	50%	30%	-	-	--	--	100%
Cash Flow billion US$	0030	0075	0045					0 015
Plant Capacity MW	0	0	10 4	10 4	10 4	10 4	10 4	10 4
Pravdinskaya								
Cash Flow %	20%	50%	30%	--	-	-	--	100%
Cash Flow billion US$	007	0175	0105					0 035
Plant Capacity MW	0	0	12 7	12 7	12 7	12 7	12 7	12 7
TOTALS								
Cash Flow %	10%	17%	17%	16%	14%	13%	13%	100%
Cash Flow billion US$	4443	7289	732	6711	5837	540	540	4 240
Plant Capacity MW	800	1000	1374	2653	4553	6227	6861	6861

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