OSHPC BARKI TOJIK

TECHNO-ECONOMIC ASSESSMENT STUDY FOR ROGUN HYDROELECTRIC CONSTRUCTION PROJECT

PHASE II REPORT (DRAFT FINAL): PROJECT DEFINITION OPTIONS

EXECUTIVE SUMMARY

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TECHNO-ECONOMIC ASSESSMENT STUDY FOR ROGUN HYDROELECTRIC CONSTRUCTION PROJECT

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SYNOPSIS

Techno-Economic Assessment Studies (TEAS) for the Rogun Project have been carried out by a consortium of Coyne et Bellier of France, Electroconsult of Italy and IPA of the United Kingdom. Separately, but in parallel, an Environmental and Social Assessment (ESIA) has been developed by another Consultant (Poyry Energy Ltd. of Switzerland).

Construction of the Rogun Hydropower Project (Rogun HPP) began in 1980 and was then interrupted by political changes resulting from the independence of Tajikistan. Construction began again in 2008, but since 2012 only safety-related and maintenance activities have been carried out pending the completion of the assessment studies.

The TEAS has been undertaken in three phases. Phase 0 is an assessment of the potential impact of the salt wedge that exists at the Rogun site. It was concluded that this impact can be addressed by appropriate mitigation measures to ensure the long-term safety of the proposed dam. Phase I is an assessment of all previous work done to date on the Rogun HPP site. It was concluded that, with implementation of specified remedial measures, the existing facilities and equipment were suitable for use in the project.

Phase II is a techno-economic assessment of different alternatives of the Rogun HPP. Three full supply level (FSL) alternatives have been studied: FSL at 1290 masl, at 1255 masl and at 1220 masl. These correspond to dam heights of 335 m, 300 m and 265 m respectively. Three installed capacities have been studied for each FSL, resulting in a total of nine Rogun alternatives studied.

The designs of the proposed alternatives have been developed on the basis of design criteria in line with current international practice for such dams, and taking into account the specific features of the proposed Rogun site. The assumptions regarding reservoir filling and subsequent project operation are consistent with the existing agreements and practice for water allocation of the Vakhsh River. Considering the long duration of the construction period for all the alternatives, an early impounding and early generation concept has been adopted for all alternatives. Detailed cost estimates (including social and environmental costs) and implementation schedules have been developed for each alternative.

The findings of the technical assessment are:

- The site is appropriate for the proposed dam.

- A rockfill dam with a central impervious core is the most appropriate type of dam for the Rogun site.

- All three dam alternatives can safely withstand the peak ground acceleration corresponding to the maximum credible earthquake.

- The quality of the available hydrological data was judged acceptable as an input for the estimation of design floods, and the simulation of reservoir operation and future power production.

- All alternatives can be constructed to safely withstand design floods for different construction phases and extreme floods during operation; the two highest dam alternatives can also attenuate the Probable Maximum Flood sufficiently to protect Nurek dam and the rest of the Vakhsh cascade.

- The Vakhsh river carries a very heavy sediment load and the Rogun reservoir will eventually be filled with sediment; the estimated life for the different dam height alternatives varies from 115 years for the highest dam alternative to 45 years for the lowest dam alternative. A specific end-of-life strategy to ensure dam safety has been developed for all dam alternatives.

Based on this technical assessment, the Consultant has concluded that, subject to the specified design modifications and the implementation of the identified mitigation and monitoring measures, any of the Rogun dam alternatives can be built and operated at the Rogun site within international safety norms.

A detailed risk register has been developed for the project to exhaustively identify potential future risks for all alternatives, if the project were to be implemented. All project alternatives have been found to have the same list of risks.

Detailed economic analyses have been performed for the different project alternatives and compared with no-project scenarios. This included:

- Preparing a detailed analysis of future electricity demand in Tajikistan.

- Developing a regional least-cost generation expansion plan for each of the nine Rogun alternatives and also for options excluding Rogun.

- Assessing the economic benefit of each alternative evaluating the impact on the present value of total system costs in Tajikistan, and thereby determining the least-cost option for Tajikistan.

- Preparing stand-alone economic analyses for the different alternatives in terms of their net present value and economic internal rate of return (“EIRR”).

- Conducting a large number of sensitivity analyses to assess the robustness of the results.

The economic assessment demonstrates the economic viability of all the Rogun alternatives under a wide range of assumptions. The FSL 1290 masl alternative with installed capacity of 3200 MW shows the highest total system cost saving and the highest net present value of economic benefits.

In summary, the highest dam (FSL 1290)

- can be built and operated at the Rogun site within international safety norms;

- has the longest project life, thereby guaranteeing low cost energy production for the longest period to the Tajik energy system;

- can attenuate the PMF sufficiently to safeguard the entire Vakhsh cascade for about 100 years;

- would provide a longer delay in the sedimentation of the Nurek reservoir and the consequent impact on electricity generation from the entire cascade;

- provides the maximum potential for augmenting dry year flows for downstream riparians;
- is part of the least cost generation expansion plan for Tajikistan in preference to other Rogun alternatives as well as No Rogun alternatives; and
- provides the highest net present value of economic benefits.

Based on the above assessment, the Consultant has recommended that the 1290 FSL Rogun alternative be taken forward for detailed consideration. As the economic results provided by different installed capacities are relatively similar, it is recommended that the optimization of the installed capacity be studied further in the detailed design stage.

1 INTRODUCTION

This section is an executive summary of the assessment carried out by the Consultant under Phase II of the Techno-Economic Assessment Studies (TEAS) for the Rogun Project. The TEAS Consultant comprises a consortium of Coyne et Bellier of France, Electroconsult of Italy and IPA of the United Kingdom.

Separately, but in parallel, an Environmental and Social Assessment (ESIA) has been developed by another Consultant (Poyry Energy Ltd. of Switzerland).

The TEAS has been undertaken in three phases. Phase 0 of the studies is an assessment of the measures required to mitigate the potential impact of the salt wedge that exists at the Rogun site. The Summary of the Phase 0 report has been previously disclosed publicly.

Phase I is an assessment of all previous work done to date on the Rogun HPP site. The Summary of the Phase I report has been previously disclosed publicly.

Phase II is a techno-economic assessment of different alternatives of the Rogun HPP. A rigorous technical assessment has been carried out. Detailed economic analyses have been performed for different project alternatives and compared with no-project scenarios. The economic analyses take into account the social and environmental costs provided by the ESIA Consultant. Based on the techno-economic assessment, the Consultant has recommended an alternative for further consideration. A financial analysis has been performed for the recommended alternative.

2 BRIEF PROJECT HISTORY

The Rogun Hydropower Project (Rogun HPP) was first conceived in the Soviet Union in the 1950s and 1960s as part of the regional development of what are now several independent states. The original purpose of the Rogun project has evolved from supporting regional irrigation and hydropower generation, to the present plan, which calls for Rogun to serve as a hydropower project with additional benefits provided by the project relating to flood control and sediment management.

The Rogun HPP site lies about 110 km east of Dushanbe, and the HPP would become the uppermost of a planned and partly built hydropower cascade on the Vakhsh river. Of most importance is the Nurek HPP, 70 km downstream from Rogun, which has operated since the 1980s. The Nurek HPP includes a high dam – at 300 meters high, this is currently the highest embankment dam in the world. The other HPPs in the cascade are run-of-river (ROR) schemes with little or no storage capacity.

Construction of the Rogun HPP began in 1980 and was then interrupted by political changes resulting from the independence of Tajikistan and the other Central Asia countries. Construction began again in 2008, but since 2012 only safety-related and maintenance activities have been carried out pending the completion of the technical, economic, environmental and social assessment studies.

3 DESIGN APPROACH

As per the scope of services defined in the Terms of Reference, an extensive techno-economic assessment has been carried out, taking into account all existing design work made available to the TEAS Consultant. These included updated designs prepared by Russian Consultants (Hydroproject Institute of Moscow) in 2009 and 2010.

All design change recommendations resulting from this assessment strictly comply with the design criteria developed by the TEAS Consultant in line with internationally accepted standards and state of the art engineering practice for large hydropower projects. These design criteria have been established with the objective of ensuring quality, performance, sustainability and cost optimization.

The same design criteria have been applied to the assessment of the different project alternatives, ensuring a uniform basis for the assessment of these alternatives.

4 PROJECT ALTERNATIVES CONSIDERED

The following three full supply level (FSL) alternatives have been studied: FSL at 1290 masl, at 1255 masl and at 1220 masl. These correspond to dam crest elevations of 1300 masl, 1265 masl and 1230 masl, with corresponding dam heights of 335 m, 300 m and 265 m respectively.

The FSL 1290 is the maximum FSL foreseen in the 1978 design; it was not considered recommendable to exceed this height on safety and environmental grounds.

The FSL 1220 is the minimum level for a storage project with an expected reservoir life of about 50 years. Any configuration with a FSL level below 1220 is expected to be a run of river scheme, with a limited life due to sedimentation.

The FSL 1255 was an intermediate alternative.

Additionally, three installed capacities have been studied for each full supply level, resulting in a total of nine alternatives studied. These installed capacity alternatives are:

- FSL 1290: 3600 MW, 3200 MW, 2800 MW
- FSL 1255: 3200 MW, 2800 MW, 2400 MW
- FSL 1290: 2800 MW, 2400 MW, 2000 MW

5 FACTORS CONSIDERED IN DEVELOPMENT OF PROJECT ALTERNATIVES

The designs of the proposed alternatives have been developed on the basis of design criteria in line with current international practice for such dams, and taking into account the specific features of the proposed Rogun site described below.

5.1 NATURAL CONDITIONS

5.1.1 Geology and Salt Wedge

The proposed alternatives duly account for the complex geology of the site. An extensive review of the existing data and the additional site investigations performed have allowed, during the course of the assessment, a fuller understanding of the site conditions, in particular related to the downstream right bank.

The presence of a salt wedge located within the dam footprint of all alternatives has been studied in detail. This is the subject of the Phase 0 assessment that included numerical modeling and physical investigations to analyse this issue. All alternatives are equally exposed to the potential impact of the salt wedge. The mitigation measures designed combine a hydraulic curtain with grouting of the wedge cap. A complete monitoring plan has been set up to ensure that the efficiency of these measures is maintained throughout the project life. The design incorporates measures that will permit remedial works to be undertaken, if and when required, to restore the efficiency of the mitigation measures. The analysis has shown that, with the implementation of the recommended mitigation and monitoring measures, this risk can be adequately addressed to ensure the long-term safety of the proposed dam alternatives.

5.1.2 Seismicity

A deterministic approach, based on the characteristics of the faults in the vicinity of the site, has been adopted to assess the seismic design parameters to be used in Phase II to check the stability of the different dam alternatives. All three different dam alternatives are designed to withstand the Peak Ground Acceleration corresponding to the Maximum Credible Earthquake (estimated to be 0.71g). This is in full compliance with international design criteria adopted for dams of this size.

An independent Probabilistic Seismic Hazard Assessment (PSHA) has been carried out also for use in the detailed design stage. For the design parameters obtained from the PSHA, a preliminary analysis has shown that the dam response and displacements are within the limits obtained from the analysis performed with the design parameters obtained from the deterministic approach.

Co-seismic displacements in case of large earthquakes have been estimated for the faults that cross the footprint of the dam and appropriate measures incorporated in the design of the project structures (tunnels, etc.).

The impact of Reservoir Triggered Seismicity has been assessed based on the Nurek data; the earthquake that can be triggered by the reservoir is several magnitudes lower than the Maximum Credible Earthquake.

It has been recommended that seismic monitoring be undertaken prior to, during and after construction of the dam.

5.1.3 Hydrology

Hydrological data on inflows at the proposed Rogun Dam site is taken from the following sources covering a period of 76 years:

- 1932 to 1972 – discharge recorded at Tutkaul gauging station.
- 1973 to 1988 – discharges at Tutkaul reconstituted from observations made at Komsomolabad (correlations between the two stations are based on periods of common recording: 1949-57 and 1963-72).
- 1988 to 2008 – discharges calculated based on Nurek HEP inflows.

The quality of the observed data was confirmed to be generally consistent and reliable, and acceptable as an input for the simulation of reservoir operation and future power production.

The extreme floods considered for the protection of Rogun dam are the Probable Maximum Flood (PMF) and the 10,000 years return period flood. As the Vakhsh discharge is mostly uncorrelated to the precipitation, the assessment of the PMF was based on the degree-day method. The PMF has been evaluated as 7,800 m^3/s (daily average). The 10,000 years return period flood has been derived as 5,700 m^3/s from the above hydrological series.

Design floods for the construction stage have also been derived from the above series, taking into account the period of exposure of the relevant construction stage.

5.1.4 Sedimentation

The sedimentation study has been based on available data, including existing surveys of the Nurek reservoir. In order to appropriately address uncertainties, a conservative approach has been used to define the different lifetimes of the proposed alternatives assuming an annual inflow of sediments in the reservoir of 100 million m^3/year. The estimated life for the different dam height alternatives is as follows:

- 1290 FSL 115 years
- 1255 FSL 75 years
- 1220 FSL 45 years

Additional studies have been recommended on the quantum and characteristics of the sediment load to enable the detailed design of a complete sediment management plan. This will also assist in clarifying the operating lifetime projections.

Reservoir sedimentation and the progression of the sediment delta towards the dam can be partly controlled by the reservoir operating conditions and by modification of the level of the intakes during the life of the project to extend the generation phase.

Nevertheless, due to the high level of sediment inflows in the Vakhsh River, the reservoir will be filled with sediment eventually. Therefore, a specific end-of-life strategy for all dam alternatives is required.

5.2 Existing Facilities and equipment

All alternatives have been designed to appropriately incorporate the existing facilities previously constructed at the Rogun site and the equipment already ordered. A thorough assessment of these facilities and equipment was carried out in the Phase I assessment. The aim of the assessment was to determine the suitability of the existing structures and equipment with respect to the proposed Rogun alternatives. Where necessary, remedial measures have been designed to bring the existing structures up to the safety and performance standards required for the project.

All three proposed alternatives incorporate existing equipment and facilities to the extent possible so as to minimize the overall project cost.

Each Rogun alternative is planned to work in tandem with the Nurek dam in order to derive full benefits from what is a major asset in the overall Tajik existing hydropower portfolio.

5.3 Reservoir Filling And Operation

The assumptions regarding reservoir filling and subsequent project operation are consistent with the existing agreements and practice for water allocation of the Vakhsh River.

Future use of its water share by Tajikistan has been incorporated in the model, in accordance with the existing practice for water allocation on the Vakhsh River and the stated intent of the Government of Tajikistan. Reservoir filling would use the currently unutilized Tajik share; subsequently, the Government of Tajikistan intends to use the unutilized Tajik share for irrigation.

During the operating phase, the combined reservoirs of Rogun and Nurek will be operated in a manner ensuring that the water volume transferred from summer to winter is consistent with that transferred at present (4.2 bcm).

Each of the proposed dam alternatives can be operated under this regime; the time required for filling the reservoir and the energy production is based on this regime.

5.4 Environmental and Social Impacts

The Environmental and Social Impact Assessment (ESIA) was carried out in parallel by the ESIA consultant based on the technical features of the proposed alternatives defined in the Phase II Report.

The analysis of environmental and social impacts of the three dam height alternatives carried out by the ESIA consultant did not lead to elimination of any of the proposed alternatives. It was determined that the environmental and social impacts of all three alternatives could be adequately mitigated – although the highest dam does require significantly more resettlement than the other two dam height alternatives.

All environment and social costs for the different dam alternatives, as assessed by the ESIA consultant, were taken into account to derive the overall capital cost of each proposed alternatives. In addition, the annual value of lost agricultural production from land impacted by the reservoir for each alternative has been included in the economic analysis.

5.5 Electricity Demand Forecast

A detailed forecast of domestic demand growth, including assessment of currently unmet demand, has been carried out.

Electricity demand in Tajikistan peaks in winter. However, the mismatch caused by the greater electricity generation in summer from the predominantly hydropower-based system and the higher demand in winter results in summer surpluses and winter shortages. Recent winters have seen up to 50% of demand remaining unserved in the worst affected months. The unserved part of demand is suppressed by means of load shedding, which is achieved by cutting off the supply to certain parts of the grid (mostly residential) for various periods of time.

A detailed analysis of future electricity demand and gross generation requirement in Tajikistan was carried out, considering a range of estimates for unserved demand, the potential future impact of both economic growth and electricity tariffs on consumption, and expected developments in the country's electricity system to introduce energy efficiency measures and reduce transmission and distribution losses. The median compound annual growth rate ("CAGR") to 2050 was forecast at 2.6%, while the 25th and 75th percentiles (that form the basis of the low and high sensitivities) range from 2.0% to 3.6%.

All Rogun alternatives will generate electricity that can be used to meet domestic electricity demand and will also provide summer surplus electricity for exports via interconnectors to neighboring countries. Furthermore, given the significant current winter shortages, all alternatives will incorporate design features that permit early electricity generation from the project during the construction phase.

6 PRINCIPLE FEATURES OF THE PROJECT ALTERNATIVES

Based on a consideration of the factors listed in the previous Section, appropriate layouts and designs of the different alternatives were developed in sufficient detail to enable a techno-economic assessment to be carried out. The same design criteria have been used to develop the design of the different alternatives, all of which are considered to be technically feasible.

The principal features of the alternatives are described in this Section.

6.1 Selection of the dam site, type and axis

6.1.1 Dam Site

The dam site was originally selected on the basis of the following considerations:

- The topography at the selected site results in a very narrow valley compared to the rest of the river; this allows construction of a high dam with a relatively limited quantity of materials, thereby incurring significantly lower overall costs.
- Upstream of the Rogun site, the Ionakhsh Fault runs along the river on the same axis. Therefore, the dam core for an upstream site would have been set across an active fault, which would not be acceptable.

These considerations remain valid and the site is considered appropriate for the proposed dam.

6.1.2 Dam Type

A number of possible dam types were considered. These included a rockfill dam with an impervious core, a concrete arch dam, a concrete-face rockfill dam, a roller-compacted concrete (RCC) gravity dam, a RCC arch gravity or arch dam, a rockfill dam with an earth core and an upstream concrete block cutting the heel, and a rockfill dam with an earth core dam with a downstream concrete block cutting the toe.

The suitability of each dam type was assessed for the specific characteristics of the Rogun site, including the following aspects:

- Height of the proposed dam
- Ability to withstand large seismic events
- Ability to adapt to the salt wedge
- Avoiding excessive stresses on the siltstone in the foundation of the dam
- Ability to withstand differential settlements
- Ability to deal with flood underestimation

- Possibility of construction in stages and gradual filling of the reservoir
- Construction duration

Based on a detailed comparison, it has been concluded that a rockfill dam with a central impervious core is the most appropriate type of dam for the Rogun site.

6.1.3 Dam Axis

The layout of the dam has been reviewed keeping in view the characteristics of the Rogun site (location of salt wedge, tectonic features, intakes of the diversion tunnels, etc.). It has been concluded that the axis of the dam as given in the original design should be maintained for the three dam height alternatives.

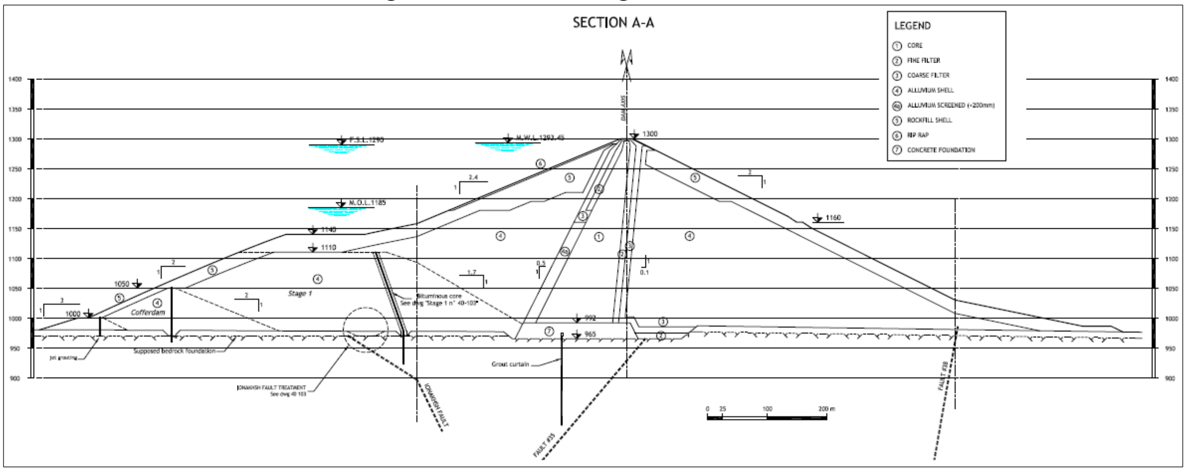
6.2 **Design of the Dam**

In order to develop the design of the dam, analyses were performed of the dam response to an extreme seismic event (MCE with a peak ground acceleration of 0.71g) and the resulting displacements were evaluated. These analyses were carried out for three different cross sections of the dam: one in the river bed, one on the right bank and one on the left bank. The corresponding dam height in these cross sections ranges from 160 m to 335 m. This allows studying of the sensitivity of the results with respect to the dam height.

The results show that, even though the dynamic behavior is slightly different from one dam height to another, the overall displacements are in the same range of magnitude. Therefore the following conclusions are applicable to each of the three dam alternatives and are used to derive the corresponding typical dam cross section (see below):

- Dam slopes should be as follows: 2H/1V downstream and 2.4H/1V upstream above the large berm level and 2H/1V below. These slopes have been found sufficient to ensure the stability of the dam.
- Given the range of horizontal displacement found, filters and transitions thickness should be at least 10 m to ensure their effectiveness even in the case of a large earthquake.
- The freeboard should be at least 6 m to accommodate the settlement that could occur during a large earthquake.
- In the upper part of the dam (top 50 m), rockfill should be used instead of alluvium as it has a higher friction angle.

Figure 1: Dam – Longitudinal section



With these design features, the safety of the Rogun dam is ensured under static and seismic conditions.

A stability analysis of the Stage 1 dam (an intermediate construction stage of the main dam allowing for early electricity generation) has also been carried out. The results show that upstream and downstream slopes of the Stage 1 dam are sufficient to ensure the stability of this construction phase.

As the cofferdam has the same material, the same upstream slope, a flatter downstream slope, and a lower height than the Stage 1 dam, the cofferdam stability is also ensured.

A detailed assessment of the available construction materials has been conducted. It has been assessed that adequate volumes of suitable construction materials are available for the dam fill and for concrete aggregates at the Rogun site for all alternatives.

An instrumentation plan has been developed to ensure that dam performance over its lifetime can be appropriately monitored.

6.3 Powerhouse Cavern

The powerhouse cavern has already been partly built in a sedimentary complex composed of sandstone and siltstone. The present status of the powerhouse has been discussed in detail in the Phase I assessment, in which the existing situation was described and the progress of the analyses carried out reported.

As a conclusion, a set of stabilization measures has been developed, which include rock anchors 35 m long on both sidewalls and stabilization/strengthening of the rock mass of the pillar between the powerhouse and transformer bay caverns in the Units 5 and 6 zone, to be achieved by installing steel piles with properly spaced valves to allow for consolidation grouting. As a possible alternative, an intensive consolidation grouting campaign can be carried out and tendons with two heads crossing the whole pillar in between the two caverns be installed. The most adequate solution shall be evaluated in detail at a later design stage.

While assessing the stability of the existing works, consideration was also given to possible alternative powerhouse locations. It was concluded that, with implementation of the stabilization measures, the existing location is the most appropriate for the implementation schedule and from an economic point of view.

The maximum installed capacity considered in the studies of the alternatives is 3,600 MW, which is the capacity for which the present structure has been designed. Thus, the existing powerhouse can accommodate the generation equipment corresponding to the various alternatives proposed in the studies, without need for significant modifications.

6.4 Flood Management

Detailed studies have been undertaken to ensure that the design caters for safe management of floods both during the construction phase and the subsequent operation phase. These have resulted in a number of significant modifications to the 2010 design.

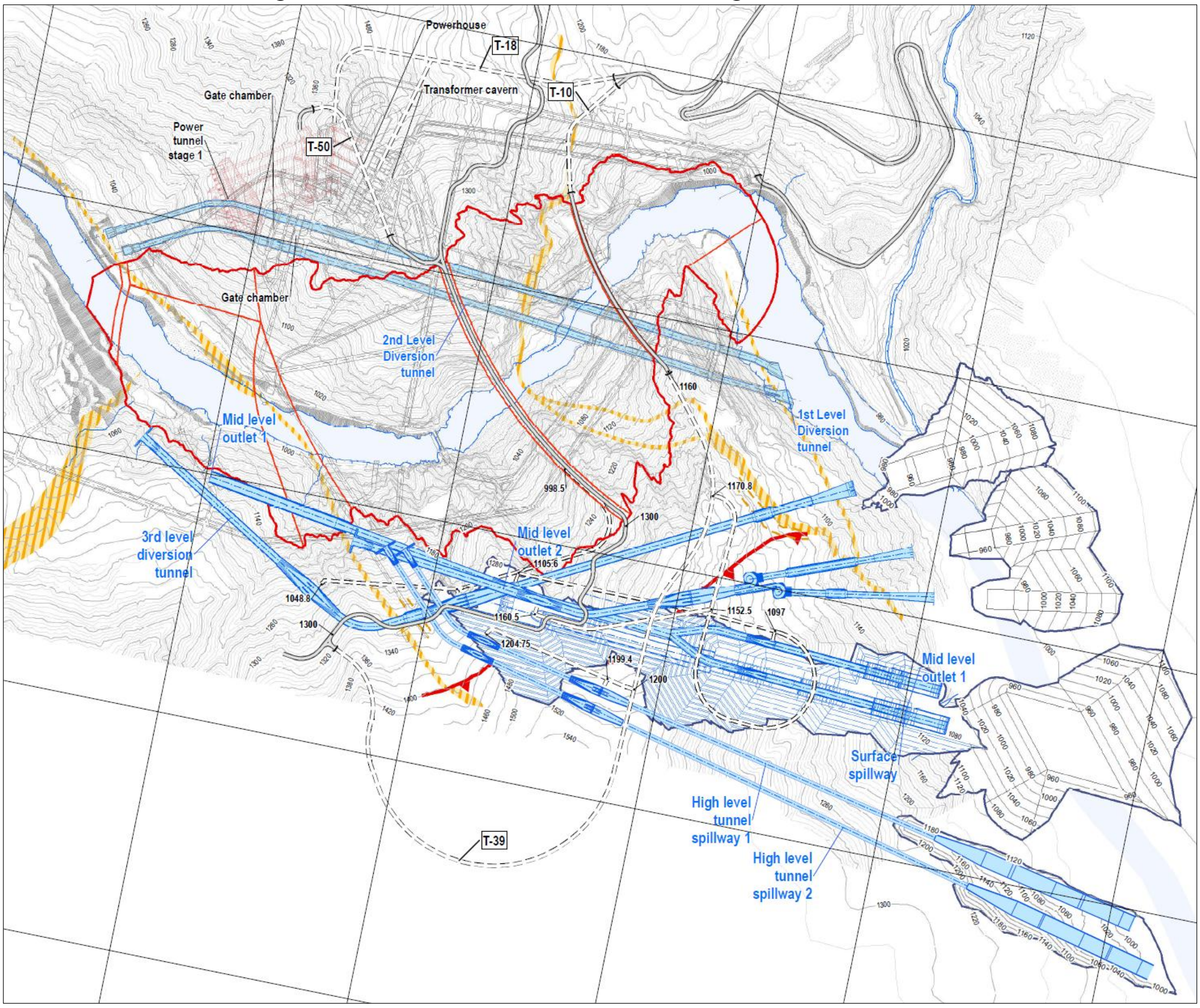
Dealing with construction floods during diversion requires a higher cofferdam and completion of the third diversion tunnel, as well as completion of the remedial measures for the two existing diversion tunnels. During subsequent construction phases, a series of new tunnels will be required as the reservoir fills.

For the operation phase, modified arrangements have been foreseen to deal with the design extreme floods, incorporating both tunnels and modules of the surface spillway. These arrangements are different for each of the three dam height alternatives.

The initial design of the Rogun envisaged only tunnel spillways with submerged intakes. The inherent risks in such a design are cavitation caused by high water velocities and degradation caused by introduction of abrasive sediments. Therefore, a long-term solution was developed in order to safely pass the design flood when spillway tunnels will be put out of operation by sedimentation.

The existing Nurek dam downstream of Rogun as well as the other projects of the Vakhsh cascade are not designed to withstand the Probable Maximum Flood, as required by current international practice. The 1290m and 1255m alternatives would have the major additional benefit of also protecting the entire downstream cascade, including Nurek, by storing part of the flood. The lower 1220m option would not be able to protect the cascade and would necessitate large additional investments to protect the cascade from the Probable Maximum Flood.

Figure 2: Alternative 1290 – Flood management structures



6.5 **Construction Stages**

Rogun dam construction is phased in several construction steps: the pre-cofferdam, the cofferdam, the Stage 1 dam and the full-height dam.

The pre-cofferdam is used to start the river diversion, and is constructed of large blocks and random filling material.

The cofferdam has a crest elevation of 1,050 masl and includes a bituminous core.

The Stage 1 dam is an intermediate stage of the full-height dam designed to allow early electricity generation. The crest elevation of the Stage 1 dam is 1110 masl for the 1290 FSL, 1090 masl for the 1255 FSL and 1075 masl for the 1220 FSL.

6.6 Implementation Schedule and Logistics

All alternatives have been thoroughly analyzed to derive a detailed construction schedule. The resulting different construction periods for the three dam alternatives are as presented in the next table:

	FSL 1290	FSL 1255	FSL 1220
TEAS validation and GoT decision to proceed with the Project	0	0	0
River Diversion date	28	28	28
End of cofferdam construction	36	36	36
End of stage 1 dam construction	58	53	49
End of dam construction	163	142	120

Table 1: Implementation Schedule - Key data 1 - Time from Pre-Contract (in months)

The extent to which facilities, existing infrastructure and access tunnels need to be developed for construction works of the magnitude of the proposed Rogun project are similar for all alternatives. Implementing any of the different alternatives will require sustained quality control and organization on site. It is to be noted that the main difference in project construction period is related to the dam fill placement. This means that activities with a high level of risk and contingencies such as underground structures and tunnels are of a similar nature for the three alternatives. Consequently, in this particular case, an increased construction period does not necessarily mean an increase in implementation risks for a given option.

For all project alternatives, due to the very challenging nature of the Project and of its tight scheduling, the Consultant recommends the careful selection of experienced and highly qualified Main Contractor/Contractors (and potentially Sub-Contractors) as well as Designers and Owner's Engineers.

6.7 Early Generation Concept

Considering the long duration of the construction period for all the proposed dam alternatives, an early impounding and early generation concept has been adopted for all alternatives. This will allow for the early generation of benefits during the lengthy implementation (filling) stage of the project.

During construction, the operation of Rogun has also been optimized in order to increase the energy output from the whole cascade as early as possible with the following main results:

Dam alternative	FSL 1290 masl	FSL 1255 masl	FSL 1220 masl
Time to reach Normal Operation	16 years	13 years	9 years
Additional energy produced by the cascade during construction compared with “no Rogun” option	111 TWh	69 TWh	37 TWh
Equivalent years of normal operation	7.7 years	5.5 years	3.7 years

Table 2: Energy production during construction for all dam alternatives

6.8 Energy Generation and Date of Commissioning

For the baseline scenario, the following average yearly energy outputs are expected to be produced by the different alternatives during normal operation:

Dam Alternative FSL 1290 masl	
Capacity	Average Yearly Energy in GWh
3600 MW	E_{Rogun}=14 398
3200 MW	E_{Rogun}=14 288
2800 MW	E_{Rogun}=14 066

Table 3: Average Yearly Energy - Dam Alternative FSL 1290 masl

Dam Alternative FSL 1255 masl	
Capacity	Average Yearly Energy in GWh
3200 MW	E_{Rogun}=12 391
2800 MW	E_{Rogun}=12 295
2400 MW	E_{Rogun}=12 072

Table 4: Average Yearly Energy - Dam Alternative FSL 1255 masl

Dam Alternative FSL 1220 masl	
Capacity	Average Yearly Energy in GWh
2800 MW	E_{Rogun}=10 121
2400 MW	E_{Rogun}=10 037
2000 MW	E_{Rogun}=9 800

Table 5: Average Yearly Energy - Dam Alternative FSL 1220 masl

6.9 Investment Costs

A detailed cost estimate (including unit rate analysis) has been established for each of the nine proposed alternatives with the same level of accuracy. These cost estimates have been used in the economic comparison of the alternatives.

6.10 Project Life

Based on the estimated sediment inflow, the ultimate reservoir lifespan (when there is no more regulation possible in the reservoir) is as follows for each alternative.

	Operating Lifetime
FSL=1290 masl	115 years
FSL=1255 masl	75 years
FSL=1220 masl	45 years

Table 6: Estimated Rogun reservoir ultimate lifespan

An annual inflow of sediments of 100 million m3 / year has been assumed to derive these figures. Raising of the power intakes progressively during the life of the project has been proposed in order to extend the life of each project alternative to the maximum extent possible.

The design provides for a surface overflow spillway with adequate aeration and dissipation devices in order to safely manage the design flood (i.e. PMF) when the spillway tunnels will eventually cease to function due to blockage by sedimentation.

At this end of life stage, this surface spillway could also discharge the solid inflows and manage the sediment balance, long after the plant and the tunnel spillway facilities will be put out of operation.

For all alternatives, an ultimate end of life management option would be to remove the gates from the surface spillway allowing the sediments to carve an incised channel through the spillway and underlying rock over a period of several decades. This scenario envisages that the incising river would bypass the dam structure and slowly release the sediments downstream.

Construction of Rogun will significantly decrease the sediment deposited in the Nurek, ensuring that river regulation capability will continue for a significant additional time period and also delaying the need of rehabilitation of the flood evacuation system with respect to the sedimentation issue. This is an important feature of Rogun project with respect to the overall sustainability of the Vakhsh cascade.

7 ASSESSMENT OF PROJECT ALTERNATIVES

7.1 Technical Assessment From Safety Considerations

For each of the Rogun alternatives, appropriate designs have been developed taking into account all pertinent aspects including the existing works already constructed, the site geology, seismicity, sedimentation, construction stage floods and extreme floods.

Based on these studies, it has been concluded that, subject to the specified design modifications and the implementation of the identified mitigation and monitoring measures, any of the Rogun dam alternatives can be built and operated at the Rogun site within international safety norms.

7.2 Economic Assessment

A regional least-cost generation expansion plan (covering Tajikistan, Uzbekistan, Turkmenistan, Afghanistan, Pakistan, Kyrgyz Republic and Kazakhstan) has been developed for each of the nine Rogun alternatives and also for options excluding Rogun. The Total System Costs ("TSC") for the interconnected regional power system has been calculated for each of these expansion plans. The economic benefit of each alternative was assessed by evaluating the impact on the Present Value ("PV") of TSC in Tajikistan, and thereby determining the least-cost option for Tajikistan. Stand-alone economic analyses were then prepared for the different alternatives of the Project in terms of their Net Present Value ("NPV") and Economic Internal Rate of Return ("EIRR"), using the results of the least-cost analyses.

7.2.1 Regional least-cost generation expansion plan

The least-cost analysis extends from 2013 to 2050 (the "Forecast Horizon"), and the model builds capacity and dispatches power plants in Tajikistan and the neighboring countries with the aim of satisfying demand at the minimum TSC for the interconnected region. The TSC includes annualized capex repayments, fixed and variable O&M costs, fuel costs and the cost of using interconnectors. The model allows for electricity to be transferred between interconnected countries based on the Net Transfer Capacity ("NTC") of the interconnection lines. The import-export flows are determined by the difference between marginal generation costs and the supply-demand situation in each country.

In order to assess the Project's value to the Tajikistan power system, the total system cost savings were calculated by comparing the TSC under the following two scenarios:

- No Rogun: A least-cost expansion plan analysis that excludes the Project to determine the benchmark capacity expansion plan and potential exports.

- With Rogun: Similar least-cost expansion plans assuming that each of the Rogun alternatives is built on a firm basis.

The option that provides the largest estimated cost saving is considered to be the least cost option for Tajikistan. System cost savings are calculated in PV terms in 2013 at a 10 percent discount rate.

The two higher Rogun alternatives also provide flood protection to the entire downstream Vakhsh cascade, and the costs of providing similar flood protection benefits in the TSC for the No Rogun case and the Rogun 1220 FSL alternative have been taken into account.

A considerable amount of construction work has already been undertaken at the Rogun site, including substantial underground works. In the event that the Project does not proceed, the cost of decommissioning the construction site has been included in the TSC for the No Rogun case.

The technical lifetime of the Project depends on the time for the reservoir to fill with sediment and these have been included by calculating the post-2050 value as the PV of the annual savings from 2050 to the end of the projected technical life. It has been assumed that the annual savings in 2050 drop in a linear manner to zero at the end of the projected technical lifetime of the alternative under consideration. Since in reality the effect of sedimentation will be more gradual and significant only in the last few years of the Project's life, this provides a conservative estimate for the benefits of the Project alternatives.

7.2.2 Economic analysis

The second assessment of the viability of Rogun was via an economic analysis consisting of a comparison of benefits versus costs for each Rogun alternative. Economic costs are determined on the same basis as in the TSC savings analysis. The economic benefits take into account both direct financial benefits accruing from the sale of electricity generated as well as wider societal economic benefits arising from its construction and operation.

The economic value of electricity generated by Rogun arises from both meeting domestic demand and exporting via interconnectors to neighboring countries. The economic value of these sales was calculated using the marginal (avoided) cost of generation determined by the model. For the dam alternatives which provide flood prevention benefit, the estimated avoided costs of providing similar flood protection in the absence of the Project has been included as additional Project benefits in the economic analysis for those alternatives which confer this downstream protection.

The Project costs include the resettlement and infrastructure replacement costs, and the economic analysis takes into account the annual value of lost agricultural production from land impacted by the reservoir for each alternative.

7.2.3 Key Assumptions

Tajikistan has some coal deposits but no domestic gas and relies on Hydroelectric Power Plants ("HPP(s)") to supply the majority of its electricity.

Most of the country's HPP capacity, including the 3,000MW Nurek Dam, is located on the Vakhsh River, the flow of which is primarily driven by seasonal glacial and snow melting. Flow rate and thus HPP generation is highest in the summer and falls significantly in the winter.

New build options: In the least-cost expansion modeling, several run-of-river ("ROR") and dam hydro projects, including the various Rogun alternatives and the 4,000 MW Dashtijum dam, are included as new build options for possible selection by the model according to economic merit. The generation from run-of-river hydropower options is skewed even more heavily to the summer months than is that from Rogun, and thus these projects generate even greater summer surpluses for the same level of winter output. New coal-fired plants were allowed to be built up to the limit of available coal resources. Tajikistan has limited potential for renewables such as wind, geothermal, waste-to-energy, and solar PV, and so these technologies have not been considered as significant capacity expansion options for the modeling. Gas imports for power generation and for urban space heating have been considered in a sensitivity analysis.

Interconnection with neighboring markets: For the base case modeling, it has been assumed that there are no direct electricity interconnections between Tajikistan and Uzbekistan, although the model runs show that electricity trade between Tajikistan and Uzbekistan would take place through the Kyrgyz Republic. The CASA-1000 transmission line is expected to connect Tajikistan and Kyrgyzstan to Pakistan via Afghanistan by 2017 with a capacity of 1,000 MW. There is an existing interconnection between Afghanistan and Tajikistan with an NTC of 110 MW. The CASA-1000 project will also increase this capacity by a further 300MW. A sensitivity analysis examines the implications if the CASA-1000 project were not to proceed as planned.

In addition to the existing and known planned interconnections, the model also allows for potential new interconnectors between Tajikistan, Kyrgyzstan and Pakistan to be built on an economic basis according to the relative generation economics in the neighboring countries.

Pakistan is a relatively large power market with maximum demand in the summer, currently experiencing significant capacity shortfall year round. As a result of the significant summer electricity shortfall and high cost of generation in the country, Pakistan is a very likely export market for Tajikistan's summer surplus. Afghanistan too has a very low electrification rate and currently experiences a large capacity shortfall and is therefore reliant on imports. Kyrgyzstan has significant hydroelectric potential and its power sector very much resembles that of Tajikistan. Whilst it is less likely that Kyrgyzstan will have power shortages during summer months when hydro availability is higher, as in Tajikistan, its interconnections with Uzbekistan and Kazakhstan provide alternative routes for power to be transmitted to and from these countries.

7.2.4 Main Sensitivities

In order to account for the uncertainty around the inputs used for the least-cost expansion planning, sensitivities were used to assess the robustness of the estimated cost savings and the economic value of each Rogun alternative to variations in economic and other conditions. The main sensitivities considered cover changes in four variables that were identified as likely to have a large impact on TSC:

- Demand: Electricity demand growth scenarios for Tajikistan.
- Fuel costs: Fuel price assumptions for Central Asia including Tajikistan.

- Total Investment Costs ("TIC"): The TIC of the New Build options, including the different candidate plants in Tajikistan and neighboring countries whilst keeping inputs for the Project unaffected.

- NTC: Capacity of the interconnectors from Tajikistan to Pakistan, Kyrgyzstan and Uzbekistan (including reconnection with Uzbekistan).

Central, high and low cases were determined for each of these four variables. The Reference case (base case) assumed the central forecast for all variables, and eight sensitivities were examined varying each variable in turn to its high and low value. Overall probability-weighted average TSC savings and economic NPVs for each Rogun design alternative were calculated on this basis.

Sensitivities with discount rates of 8% and 12% were also analyzed.

7.2.5 Least-Cost Generation Expansion Results

The Table below shows the PV of TSC savings for the Reference case and eight sensitivities, as well as the resulting probability-weighted average.

Table 7: PV of TSC savings by sensitivity @ 10%

	Reference	High Demand	Low Demand	High Fuel	Low Fuel	High TIC	Low TIC	High NTC	Low NTC	Probability-weighted average
1290, 3600 MW	1,678	1,854	628	1,881	1,215	2,509	554	1,051	1,485	**1,453**
1290, 3200 MW	1,707	1,825	679	1,929	1,238	2,531	560	1,072	1,542	**1,479**
1290, 2800 MW	1,701	1,452	688	1,897	1,248	2,522	538	1,071	1,552	**1,437**
1255, 3200 MW	1,495	1,687	621	1,729	1,103	2,399	580	948	1,353	**1,341**
1255, 2800 MW	1,497	1,344	648	1,739	1,099	2,410	529	944	1,436	**1,314**
1255, 2400 MW	1,524	468	635	1,672	1,106	2,395	541	937	1,380	**1,218**
1220, 2800 MW	1,389	1,432	723	1,381	983	2,047	356	936	1,111	**1,174**
1220, 2400 MW	1,387	728	734	1,315	980	2,034	348	927	1,155	**1,100**
1220, 2000 MW	1,342	69	710	1,329	933	1,980	424	866	1,228	**1,022**

The results show that all the Rogun alternatives would have an overall beneficial impact on the Tajikistan electricity system across all sensitivities, from 69USD million for the smallest Rogun alternative with High Demand growth to over 2.5USD billion for the highest dam alternatives in the High TIC case. The highest dam alternative (1290 masl) generally shows the greatest benefit across all sensitivities, except in the Low Demand case when the lower need for capacity results in slightly lower TSCs for the smaller dam alternatives. In practice, if demand were forecast to grow less quickly, new build might be deferred or result in an adjustment in the implementation schedule of the Project.

The results from the least-cost expansion modeling in all cases (No Rogun and the Rogun alternatives) indicate the need for the construction of at least one large dam (Rogun or Dashtijum) along with several new ROR HPPs. Tajikistan would also need to rely on imports from (or through) the Kyrgyz Republic to augment domestic winter generation.

Once the construction of the Project begins, the forecast cost of electricity tends to be lower under the Rogun alternatives than under the No Rogun scenario.

Electricity exchanges between countries are broadly similar in all cases, including the No Rogun scenario. Tajikistan is expected to become a net exporter under all scenarios, exporting to Pakistan and Afghanistan during summer and importing from (and through) Kyrgyzstan in winter. The largest volume of exports is to Pakistan, with the export interconnectors almost fully utilized in the summer when electricity demand in Pakistan peaks and Tajikistan has surplus energy. By contrast, power demand in Tajikistan's other neighbors peaks in winter, which limits Tajikistan's opportunities for exporting to them in summer.

7.2.6 Results of Economic Analysis

For the economic analysis, the benefits of the Project consist of the value of Project's generation for domestic use and for exports, and the flood protection that the two higher dam heights provide for the downstream Vakhsh cascade. The NPV results shown in the Table below indicate that the higher initial costs of the higher dam alternatives are outweighed by the future benefits. The highest dam height alternatives have the greatest NPVs across all the sensitivities.

Table 8: NPV @ 10% of different Rogun alternatives across sensitivities

	Reference	High Demand	Low Demand	High TIC	Low TIC	High Fuel	Low Fuel	High NTC	Low NTC 10%	Probability-weighted average
1290, 3600 MW	819	852	720	1,080	523	1,222	366	766	780	**795**
1290, 3200 MW	863	887	765	1,121	559	1,244	420	808	819	**835**
1290, 2800 MW	878	792	769	1,132	561	1,251	405	820	767	**825**
1255, 3200 MW	729	768	648	951	460	1,074	302	663	667	**699**
1255, 2800 MW	758	715	678	973	471	1,102	331	690	747	**722**
1255, 2400 MW	748	578	699	982	495	1,087	332	704	641	**701**
1220, 2800 MW	656	656	640	887	402	943	312	629	398	**618**
1220, 2400 MW	667	534	650	889	404	919	326	637	435	**613**
1220, 2000 MW	635	431	614	848	389	874	286	601	435	**575**

The above results show that the 1290 FSL 3200 MW alternative has both the highest overall TSC saving and the highest economic NPV.

7.2.7 Additional Sensitivities

In addition to the main sensitivities discussed earlier, a number of additional sensitivities were analyzed to assess the robustness of the TSC savings and economic NPV of the 1290 FSL 3200 MW alternative, and certain key breakeven values were also determined (i.e. the extent to which a particular parameter would have to change from the Reference case to reduce the benefit or value of the Project to zero).

These additional analyses covered:

- A modified reference case excluding the CASA interconnectors and allowing economic interconnector expansion only.
- Gas imports for electricity generation and urban space heating.
- Additional low demand growth scenarios.
- Delay in starting Rogun construction.
- Extension in Rogun construction timetable.
- Variations in Rogun costs.
- Achieved Rogun sale prices both domestically and exports.
- Carbon dioxide (“CO2”) emissions abatement benefit.
- Delay in receiving export revenues.

The results of these analyses demonstrate the robustness of the benefits and value of this specific Rogun alternative to a wide range of possible future outcomes, with very large movements in the variables necessary to alter the conclusions.

7.2.8 Conclusions from Economic Assessment

The economic assessment demonstrates the economic viability of all the Rogun alternatives under a range of assumptions.

The FSL 1290 masl alternative with installed capacity of 3200 MW shows the highest Total System Cost Saving and the highest Net Present Value of economic benefits. The incremental cost of implementing the highest alternative is compensated by the incremental benefits derived during the Project life. These results are reinforced with a lower discount rate, which apportions a greater weight to the long-term benefits of the Project.

From a purely economic point of view, the highest dam alternative and intermediate installed capacity (FSL 1290 masl and 3200 MW) is the most attractive option.

7.3 Other Considerations

7.3.1 Life Span and Economic Analysis

The different dam alternatives have significantly different life expectancies (115 years, 75 years and 45 years for FSL 1290 masl, FSL 1255 masl and FSL 1220 masl respectively). The difference in lifetime between the proposed dam alternatives is a significant factor as the Rogun project is a large investment for the Government of Tajikistan as well as a major asset in both the overall energy sector of the country and the region.

In addition to providing generation from Rogun for a considerably longer period, the highest dam would also provide a correspondingly longer delay in the sedimentation of the Nurek reservoir. As the Nurek reservoir becomes sedimented, the electricity generation from the entire cascade will be significantly affected. Thus the impact of the greater reservoir capacity of the highest dam will extend well beyond the life span indicated above.

With high discount rates, there are limitations in reflecting the impact of key economic parameters beyond 40 to 50 years, and thus the economic analysis does not adequately reflect the relative impact of the variations in life spans. This is evident from the sensitivity carried out with an 8% discount rate that shows significantly greater net benefits for the longer life span of the highest dam alternative.

It also seems advisable that such a strategic investment for the Tajikistan Government should not be decided based on a 40 years study window, but should be seen as a legacy for future generations. This is an important argument in favor of the highest dam (FSL 1290 masl) that provides the longest project life, guaranteeing low cost energy production for the longest period to the Tajik energy system.

7.3.2 Sustainability and Long Term Management

As discussed earlier, the end-of-life management of such a large asset will need to be planned at the design stage of the project and appropriate measures implemented, irrespective of dam height. This will require large investments (e.g. maintenance of the surface spillway used to evacuate the river flow when the dam will be filled with sediment).

The Consultant recommends putting a de-commissioning fund in place as early as possible, utilizing a part of the project revenues in order to finance these end of life costs. Financing such a fund will be easier for a project with an extended life that will provide benefits on a much larger period of time. This is another factor favoring the alternatives with a longer life span.

7.3.3 Opportunities for Cooperative Operation

The intended mode of operation of any of the Rogun alternatives will not impact the seasonal flow pattern downstream of Nurek as it complies with existing agreements and practices on allocation of water shares. However, in this operation mode, the largest reservoir at FSL 1290 masl and the intermediate reservoir at FSL 1255 masl, will not be fully utilized and have a large unused live storage capacity.

This could represent a potential opportunity for cooperation within the entire Amudarya basin, bringing additional storage capacity that could be possibly mobilized during dry years to sustain the irrigation needs of the riparian countries. The highest dam alternative provides the greatest potential for storage and the associated economic benefits this could bring. Trade-off mechanisms would need to be institutionalized between the concerned countries to better leverage these benefits as well as ensure the long-term viability of such a benefit-sharing approach.

7.3.4 Extreme Flood Safety of Vakhsh Cascade

The Nurek Dam, currently the highest embankment dam in the world, and the rest of the Vakhsh cascade is not designed to withstand the PMF, as required by current international practice.

Simulations show that only the dam alternatives with FSL at 1290 masl and 1255 masl can attenuate the PMF sufficiently to protect the downstream structures from being overtopped. This attenuation cannot be provided by the lowest dam alternative (FSL 1220 masl), thus requiring implementation of large upgrading works on the downstream cascade structures.

In order to ensure that such a positive benefit is made available to the cascade safety for the longest period of time, it would be more effective to implement the FSL 1290 masl alternative.

The investment on upgrading works on the downstream cascade structures will in any case be required when storage capacity will be lost for all alternatives; this will occur much later for the highest dam alternative.

All alternatives will require putting in place a flood forecasting system to provide adequate information on potential floods.

7.3.5 Climate Change and Carbon Release Avoidance

Reservoir projects are found to be more adaptive to variations in river discharges due to climate change. The additional reservoir capacity for flow regulation available in the two highest dam alternatives and unused in the present simulation can bring more flexibility to handle hydrology variability. This enhanced flexibility could be in terms of the ability to deal with increased flood flows or in better management of dry years. Also the reservoir capacity could be used to store earlier runoff until needed by downstream riparians for irrigation.

This goes in favor of the alternatives with the greater unused storage capacity of the higher dam alternatives.

Moreover, generation from reservoir projects can substitute for generation using fossil fuels, leading to a reduction in emissions of carbon dioxide (”CO2”). The bigger the annual hydropower energy produced, the higher the avoided emissions and therefore the potential benefits from CO2 emissions savings. This argument favors the highest dam alternative.

7.3.6 Installed Capacity and Peaking

The Least Cost Expansion Plan undertaken for Tajikistan and its neighboring countries suggests that the incremental net benefit of adding installed capacity beyond a particular point for a given dam height is limited. Average annual generation (measured in terms of energy, MWh) from each dam alternative is very similar and not affected by installed capacity. The benefit of additional peak capacity is limited by interconnector constraints and the level of achievable prices in Tajikistan and Pakistan (which is the principle export market for Tajikistan). This explains why the 3600 MW alternative at FSL 1290 masl is less attractive than the 3200 MW according to the economic analysis undertaken.

However, there are other criteria to consider such as the option of expanding installed capacity later on. One solution could be to leave one unit pit empty and decide on the installation of another unit at a later stage. Moreover if the incremental cost of adding one unit is not major, it should be noted that this additional unit could bring more flexibility in the generating system by allowing standby periods for maintenance without loss of overall annual energy generation. The incremental cost could be recovered by the avoided loss of generation during maintenance. This has to be studied in more detail in the next phase of the studies as a further optimization of the installed capacity.

7.3.7 Financial Analysis & Financing

Four hypothetical financing structures were examined for the 1290 FSL 3200 MW alternative combining various elements of (a) full government self-financing with equity, (b) a preferential loan from a foreign government, (c) multilateral and commercial loans, and (d) foreign bond issuance. The financial structures yield internal rates of return close to 12 percent.

For safety reasons, placement of the dam fill must be completed without significant interruption once construction has commenced, and thus it is crucial to ensure that full financing for the relevant contract is available prior to the start of dam construction.

The financing requirements are obviously greater for the higher dam alternatives but so is the energy generated. The results of the least cost analyses indicate that the financing requirement to provide for a similar level of electricity output would be least for the highest dam alternative.

7.4 **Risk Management**

A detailed risk register has been developed for the project to exhaustively identify potential future risks for all alternatives, if the project were to be implemented. All project alternatives have been found to have the same list of risks.

For each identified risk, feasible mitigation measures have been recommended. The objective was in each case to reduce the risks to an acceptable level in compliance with the indicated quality, safety, performance and sustainability requirements.

8 CONCLUSION AND RECOMMENDATION

As stated earlier, the technical assessment studies have shown that, subject to the specified design modifications and the implementation of the identified mitigation and monitoring measures, any of the Rogun dam alternatives can be built and operated at the Rogun site within international safety norms.

Based on the considerations given in the preceding section, the Consultant recommends that the highest dam alternative (FSL 1290 masl) is taken forward for detailed consideration. This alternative will become a major asset in the Tajik generation system as well as the regional energy market, providing sustained low cost production for the longest time span. It will also protect the Vakhsh Cascade against extreme floods with no additional investment for the longest period, avoiding complex and expensive rehabilitation works to be implemented on the Cascade. In addition to providing generation from Rogun for a considerably longer period, the highest dam would also provide a correspondingly longer delay in the sedimentation of the Nurek reservoir, and the consequent adverse impact on the electricity generation from the entire cascade.

Based on the analysis performed, it appears that an intermediate installed capacity would be sufficient (3200 MW), because of the difference in initial equipment investment and the limited additional energy generation from a greater installed capacity option. However, as the economic results provided by the different installed capacities for this dam height are relatively similar, it is recommended that the optimization of the installed capacity be studied further in the detailed design stage.

A number of recommendations have been made on further investigations and analyses that should be carried out for the detailed design of the project.