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THE TECHNICAL AND ECONOMIC

FEASIBILITY OF DEVELOPMENT OF A GAS-FIRED THERMAL POWER FACILITY IN SHEBERGHAN, AFGHANISTAN

VOLUME I: OVERVIEW

Prepared for
The Ministry of Energy and Water

Under the
U.S. Agency for International Development Afghanistan Energy Assistance Program

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PREFACE

STRATEGIC DIRECTION

The macro level strategy being pursued by the Government of Afghanistan (GoA), with support and assistance of cooperating countries, international financial institutions and the international donor community, is directed to the objectives of socio-political stability and economic growth. Within these objectives is the GoA's desire to become a stable and self-sustaining member of the world community. Inherent in achieving the objectives is the provision of enhanced economic opportunity and rising living standards for its diverse population. Overcoming years of conflict adds to the significant challenge faced by the GoA and its supporters as the GoA objectives are pursued.

As one of many entities involved in assisting the GoA in achieving its strategic objectives, the US Government through various means including the United States Agency for International Development (USAID) has and continues to commit significant resources in multiple assistance program areas. In particular, USAID has directed significant efforts to social and economic infrastructure development aimed at assisting in the achievement of the objectives of the GoA.

The interrelationship between the economic-social-political nexus that enhances societal institutional stability is generally, albeit imperfectly, understood. The provision of energy which leads to employment growth and increased personal livelihoods and well being is a well understood critical component of this nexus.

Recognizing the need for rehabilitation as well as additional development in all areas of the energy sector in Afghanistan donors have focused their joint and individual efforts to enhance the physical, human and technical capacity of the sector and its various components. Inclusive in these efforts has been a focus on enhancement of the electric infrastructure serving Afghanistan. One of the single largest programs of this focus has been the development of the North East Transmission System (NETS).

The NETS incorporates donor actions encompassing activity of USAID, the World Bank (WB), the Asian Development Bank (ADB), Kreditanstalt fur Wiederaufban (KfW), and the Government of India (GoI). The direct and limited view of the purpose of the NETS is to open up the capability of Afghanistan to take competitive advantage of lower cost imported power from the Central Asian Republics (CARs) of Tajikistan, Uzbekistan and Turkmenistan, located on Afghanistan's northern border. The indirect and broader view of the NETS is to exhibit to the world community that a commercially self-sustaining transmission entity which integrates commercially viable generation and distribution components along a socio-politically stable energy corridor can be developed in Afghanistan.

There are multiple actions, both on-going and required, as well as outstanding issues that must still be resolved to make the NETS a successful development. These actions and issues range from purely technical considerations, to commercial, legal and socio-political concerns. The Ministry of Energy and Water (MEW), in cooperation with the donors, continue to address, discuss and focus their actions in coordination meetings to resolve required actions and outstanding issues of concern. Among these, as examples, are such issues as having international commercial grade power trade agreements, sourcing of imports and positioning Afghanistan for competitive acquisition of power as well as the need for popular acceptance of the transmission corridor. The detailed vetting and definition of these issues is not the purpose of this report. The purpose of noting these issues and the broader strategy directing the development of the NETS is to put in context why this report was initiated. The report is directed to one component of the NETS, specifically the assessment of the feasibility of developing a power facility utilizing indigenous natural resources which are located in Sheberghan.

THE FEASIBILITY STUDY REPORT

This Feasibility Study Report is the result of a study conducted by Advanced Engineering Associates International (AEAI) for the Ministry of Energy and Water (MEW) funded as part of the USAID Afghanistan Energy Assistance Program (AEAP). AEAP's work on this study is part of a cooperative international effort to improve the existing physical infrastructure in Afghanistan including roads, water, and power. Post-conflict Afghanistan poses unusually difficult development challenges for its citizens and government, and for international donors. In carrying out this study, every effort was made to involve and include consideration of all potential stakeholder interests.

AEAI acknowledges the cooperation and assistance of government officials and donors in providing information and support resources and for facilitating visits to the project areas and other Government of Afghanistan (GoA) facilities. AEAI acknowledges the time and participation of donor and MEW and Ministry of Mines and Industries (MMI) advisors and staff in review meetings and for comments on the draft feasibility study released for review in June 2005.

In addition, AEAI acknowledges the work and effort of the Maunsell team who performed for AEAI assessment the site selection, plant technology selection, plant design, power plant engineering, and the environmental impact assessment. AEAI further acknowledges Gustavson Associates for their assistance in the gas supply analysis.

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ABBREVIATIONS AND ACRONYMS

AGC	Afghan Gas Corporation
AEC	Afghanistan Engineering Consultants
AEAI	Advanced Engineering Associates International, Inc
ADB	Asian Development Bank
CBR	California Bearing Ratio
DABM	Da Afghanistan Breshna Moassesa (Afghanistan Electricity Enterprise)
GoA	Government of Afghanistan
GoI	Government of India
IDOE	Independent Department of Environment
IEE	Initial environmental examination
KfW	Kreditanstalt fur Wiederaufban
Maunsell	Maunsell Ltd.
MEW	Ministry of Energy and Water
MMI	Ministry of Mines and Industries
NEPA	National Environmental Protection Agency
NETS	North East Transmission System
NLDC	National Load Dispatch Center
NGO	Nongovernmental organization
PISU	Project Implementation Support Unit
SOW	Statement of work
UNAIMS	United Nations Afghanistan Information Management Service
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
WB	World Bank
WHO	World Health Organization

ELECTRICAL TERMINOLOGY

AC	Alternating current
DC	Direct current
Distribution substation	Substation with secondary voltage of 400/230 V
Electrical losses	Difference of energy delivered and energy sent out
Grid substation	Substation with primary voltage of 110 kV or 220 kV
GWh	Gigawatt-hour (1,000 MWh)
HV	High voltage
kV	Kilovolt (1,000 volts)
kVA	Kilovolt-ampere (1,000 VA)
kW	Kilowatt (1,000 watts)
kWh	Kilowatt-hour (1,000 Wh)
Load factor	Ratio of average power demand to maximum power demand
LV	Low-voltage distribution (400/230 V lines)
MV	Medium voltage distribution (3.3 kV, 6 kV, 10 kV, 15 kV or 20 kV lines
MVA	Megavolt-ampere (1,000 kVA)
MW	Megawatt (1,000 kW)

MWh	Megawatt-hour (1,000 kWh)
Transmission system	35 kV, 110 kV or 220 kV lines
TWh	Terawatt-hour (1,000 GWh)
V	Volt (unit of voltage)
VA	Volt-ampere (unit of apparent power)
VAr	Volt-ampere reactive (unit of reactive power)
VLF	Very low frequency
W	Watt (unit of active power)
Wh	Watt-hour (unit of energy)

GAS AND POWER SYSTEM TERMINOLOGY

atm	Atmosphere
Bar g	Pressure bar gauge
bcm	Billion cubic meter
BOP	Balance of plant
ºC	Degrees Centigrade
C&A	Control and automation
CI	Compression ignition
CO	Carbon monoxide
CO_2	Carbon dioxide
CCGE	Combined cycle gas engine
CCGT	Combined cycle gas turbine
DCS	Distributed control system
DEA	Diethanolamine
DEG	Diethylene glycol
EIA	Environmental impact assessment
EMP	Environmental management plan
EPC	Engineering, procurement, and construction
GE	Gas engine
gen-set	Generator set
GJ	Gigajoule
GJ/y	Gigajoule per year
GT	Gas turbine
H_2O	Water
H_2S	Hydrogen sulphide
Heat rate	Fuel consumption (kJ/kWh)
HFO	Heavy fuel oil
HHV	High heating value (gross heating value of the gas)
HMI	Human machine interface
HPHW	High pressure hot water
HRSG	Heat recovery steam generator
IC	Internal combustion
IPP	Independent power project
IPS	Instrumented protective system
IRR	Internal rate of return
kg/s	Kilograms per second

kJ/kg	Enthalpy kilojoules per kilogram
kJ/kWh	Kilojoules per kilowatt-hour
kPa	Kilopascal (unit of pressure)
kWe	Kilowatt electrical
kWt	Kilowatt thermal
LAN	Local area network
Lean burn	Air-to-fuel operating range fuel lean of stoichiometric (gives high levels of O_2 in exhaust)
LHV	Low heating value (net heating value of the gas)
MACRS	Modified accelerated cost recovery system
MCA	Multi-criteria analysis
MMBtu	1,000,000 British thermal units (293 kilowatt hours)
MWt	Megawatt thermal
MDEA	Methyldiethanolamine
MEA	Monoethanolamine
Nm^3	Normal cubic meter (0 ºC, 101.325 kPa)
NGLs	Natural gas liquids
NO_x	Nitrogen oxides
NSCR	Non selective catalytic reduction (removes NO_x, CO, and HC but only on rich-burn equipment)
OCGT	Open cycle gas turbine
ONAF	Oil Natural Air Forced (cooling method)
ONAN	Oil Natural Air Natural (cooling method)
OPC	Object linked and embedded for process control
OSH	Occupational safety and health
PAH	Polyaromatic hydrocarbon
PIC	Project implementation consultant
PLC	Power line communications
PM	Particulate matter
PVC	Polyvinyl chloride
Rich burn	Air-to-fuel operating range fuel near stoichiometric (gives little or no excess O_2 in exhaust)
SCADA	Supervisory, control, and data acquisition
Scrubbing	Stripping a particular gas from a larger volume stream
scm	Standard cubic meter (15 ºC, 101.325 kPa)
SCR	Selective catalytic reduction (can be used for NO_x reduction)
SNCR	Selective non-catalytic reduction
Sour gas	Contains H_2S greater than 5.7 mg/m^3
Sweet gas	Contains H_2S less than 5.7 mg/m^3
SO	Sulfur oxide
SO_2	Sulfur dioxide (oxidizes to give SO_3)
SO_3	Sulfur trioxide (reacts with H_2O to give H_2SO_4, sulfuric acid)
SO_x	Sulfur oxides
T&D	Transmission and distribution
TEG	Triethylene glycol
tpd	Tonnes per day
TOC	Total organic compound

VOC	Volatile organic compound
v/v	Percentage by volume
WAN	Wide area network

YEAR EQUIVALENTS AND FISCAL YEAR

March 21, 2005 is the first day of the Islamic year 1384. In this report 1379=2000, 1384=2005, 1390=2011, etc. The fiscal year for all government agencies is March 21 to March 20.

CURRENCY EQUIVALENTS

The Afghanistan currency is the Afghani (Afs). The exchange rate as of February 2005 was US $1 = Afs 49.

PLACE NAMES

The English spelling of Afghanistan place names is generally in accordance with the names used by the (United Nations Afghanistan Information Management Service) UNAIMS. However, there are sometimes variations in translation from the Afghanistan language.

EXECUTIVE SUMMARY

Advanced Engineering Associates International (AEAI) is a contractor for the U.S. Agency for International Development (USAID), within the Afghanistan Energy Assistance Program (AEAP). In February 2005, AEAI was tasked by USAID on behalf of the Ministry of Energy and Water (MEW) to undertake a comprehensive feasibility study regarding a natural gas-to-electric power generation plant to be located near the Sheberghan gas fields. This feasibility study report assesses the technical, economic, environmental, financial, commercial/structural and legal issues that impact the feasibility of the Sheberghan Project.

INTRODUCTION

USAID's overall program for the power sector in Afghanistan has been closely coordinated with the Government of Afghanistan (GoA) and with other international donors active in the Afghanistan power sector. These include the World Bank (WB), the Asian Development Bank (ADB), Kreditanstalt fur Wiederaufban (KfW), and the Government of India (GoI).

The Sheberghan Project is a key recommendation of the Afghanistan Power Sector Master Plan, prepared by Norconsult in October 2004 and updated in December 2004. The Master Plan was funded and published by the World Bank for the GoA. In part it states that:

> "The Feasibility Study of a gas fired power plant at Sheberghan or Mazar should be initiated soonest. The plant would contribute to covering demand growth in the north and depending on the size and timing, also in the Kabul Region."

USAID's plan for implementing the Project also follows the Master Plan, which recommended in part that:

> "Work on confirming volumes and quality of available gas reserves at Sheberghan should start soonest and be concluded within one year. No financing of projects related to gas utilization can be expected until confirmation of quality and volumes of available gas is in place. It is assumed that confirmation of reserves will be covered in the gas component of the ongoing ADB project TA 3874-AFG."

EXISTING ELECTRIC SUPPLY

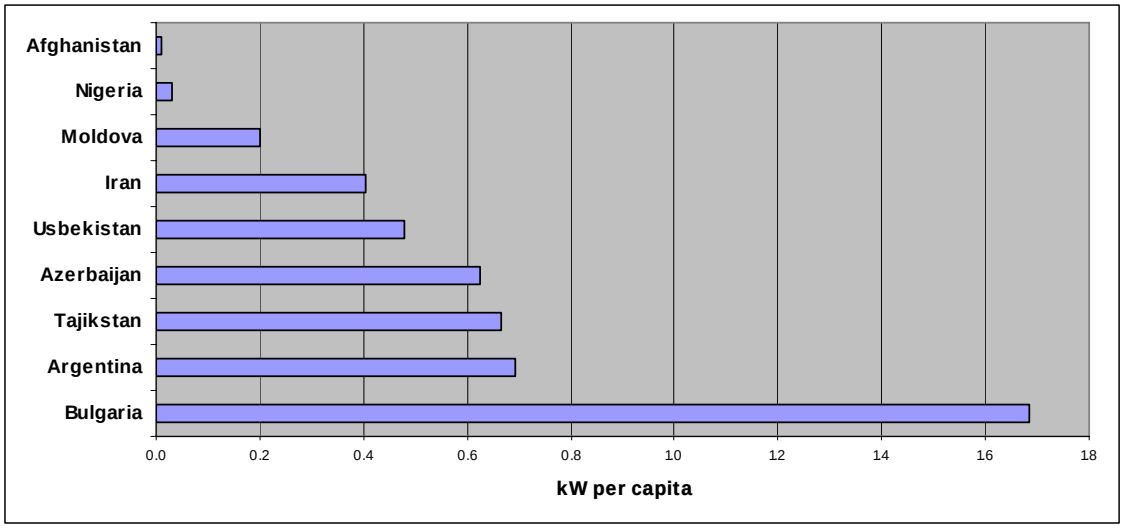
The electric power system in Afghanistan is in need of considerable rehabilitation and expansion. Existing facilities provide, at best, only unreliable service, in most places for only a few hours each day. Of 450 MW of installed electric generating capacity, approximately 215 MW are presently available, and most units are now undergoing or are well overdue for overhaul or for total replacement.

Distribution systems in the country are predominantly dilapidated or virtually nonexistent, due to war damage, insufficient investment, lack of maintenance, and theft of materials over the last 25 years. Donors are addressing the issue of upgrading and expanding power distribution (as distinct from new power supply). It is assumed that there is a clear understanding that addressing the power supply shortage must be done at the same time, or before, upgrading and expanding power distribution. If the power distribution system is upgraded and expanded ahead of the power supply, it will not solve but rather exacerbate the existing problem of poor service for the customers.

The physical problems in the power sector are compounded by other problems: legal, regulatory and administrative. Da Afghanistan Breshna Moassesa (DABM), the state-owned electric power company, does not have an appropriate governance structure or the financial resources to improve the country's electricity generation, transmission, or distribution services. It conducts limited effective and transparent accounting for revenues and expenses, physical assets, electric

power, or its personnel. As a state-owned "corporatized" entity, DABM is supposed to depend on its own resources for its operational and investment funds. However DABM has been financed mostly by transfers from the GoA and from donors.

Afghanistan has about 215 MW of operational power capacity for 23 million people—one of the lowest levels of electrification (per capita) in the world. The demand for power is unusually unpredictable by conventional methods because the rate of electrification is so low. The following chart shows the relative status of the power sector in Afghanistan, compared to that of other select developing countries.[1]



Power Supply per Capita

As a result of evaluating the power supply and demand balance, and consistent with the Master Plan adopted by MEW as a basic foundation for planning, it has been concluded that:

- There is a dire need for the electrical energy that could be supplied by this Project.
- Alternative supply options from outside Afghanistan are, at present, open to difficult and complex technical and commercial implementation issues which are being addressed separate from this study.
- Alternative potential supply options within Afghanistan, which are largely hydroelectric or coal, will take a much longer time period to develop.
- Donors agreed to target October 2008 to commence operations of the NETS. This requires a focused effort, with rapid and consistent coordinated action by all participating donors in order to bring the Sheberghan Project on line at the required time.

PROJECT DEFINITION

As a critical national priority, GoA has established the need to develop its own electric power resources, and to supplement these domestic resources with imports. The GoA requires clarity concerning its domestic resource options, both to plan effectively, and to improve Afghanistan's basis for negotiating future import contracts.

The GoA has indicated that priority must be given to power supply projects that can be implemented in the short- to mid-term (2006–2008). This feasibility study serves to meet part of

[1] CIA (2003). The World Factbook, US Central Intelligence Agency. http://www.cia.gov/cia/publications/factbook/.

the strategic needs of the GoA, as one component of the North East Transmission System (NETS).

Currently, it is planned that the NETS will transmit imported power received from the neighboring Central Asian Republics (CARs) of Uzbekistan, Turkmenistan, and Tajikistan. The NETS will also receive and transmit power from domestic generation facilities such as the Sheberghan project, and various hydroelectric facilities: Naghlu, Mahipar, and Sarobi. The overall power sector strategy for Afghanistan includes new construction and rehabilitation, where required, inclusive of the NETS. The overriding objective of the NETS is to provide the future foundation for the least-cost electric power supply for northern and eastern Afghanistan, including the Kabul grid. The Sheberghan Power Project will become an integral part in the development of the NETS.

The overall goals of the Sheberghan Project are to:

- Revitalize the natural gas industry through the establishment of an efficient and paying “anchor” customer.
- Expand electric power capacity through a domestically based power facility using domestic fuel reserves and by developing a secure and cost competitive electric power source.

The first goal requires viewing the Project’s “value chain” from the gas field wellhead to the busbar of the power plant. This includes the need to assess gas treatment and collection systems. These have been incorporated into the study.

The second goal will be realized by providing (1) improved grid stability, thus further enhancing the North East Transmission System, which is intended to provide reliable long-term power to the northern and eastern provinces of Afghanistan, and (2) increased potential bargaining power, as Afghanistan pursues firm long-term power imports from Turkmenistan, Uzbekistan, and Tajikistan.

Natural gas was formerly a vibrant and economically justified industry in northern Afghanistan. There are still existing useful assets (gas fields, wells, and data) in places that reflect past significant sunk costs. With a relatively low-cost incremental capital program, the existing assets could form the basis of a cost-effective and efficient domestic energy resource with many advantages.

Based upon the technical assessments developed as part of the feasibility study, there is no question that a power plant can be built, operated and maintained. Based on the experience of and joint assessment by Afghan Gas and the feasibility study team, there is a high probability of achieving the required gas supply. However, field work is needed to confirm firm gas supply potential.

In this study, the following questions, which are critical to, and a part of the Sheberghan Project, are also addressed:

- Are there indigenous gas reserves existing to fuel the power plant on a long-term basis?
- What is the cost of gas production?
- Where should the power plant be located?
- What is the best equipment configuration for the power plant?
- What will be the cost of the plant? How will it be implemented?
- What will be the economics of the electric energy production?

- Why is the plant justified vis-à-vis other electric energy supply options?
- Why is the plant justified at this point in time?
- What is the most effective commercial structure of the Project that would allow the plant to be turned over to Afghanistan on a long-term self-sustaining basis?

STAKEHOLDER INVOLVEMENT

Every effort has been made to include consideration of all stakeholder issues during the performance of the feasibility study. From the outset of the study, the team contacted donors and GoA officials, to gather relevant information, to periodically update all stakeholders with interim results, to hold several follow-up meetings to gather updated information, and to review the study's preliminary and final results.

In February 2005, initial meetings with representatives of the GoA ministries were held prior to any site visits. Regional officials of the Ministry of Mines and Industries (MMI) and the Ministry of Energy and Water (MEW) accompanied the team on site visits, and generously made themselves available for technical clarifications, such as on the existing and potential gas resources, existing well field infrastructure, and transport infrastructure in and around Sheberghan and Mazar-e-Sharif. Prior to initial site visit data collection and site selection, the following emerged from these meetings:

- The rehabilitation of existing gas wells to supply gas to the power station is a better option than reliance on unproven well fields.
- Gas extracted in the future from existing fields will require sweetening.
- Landowners (other than the government) of potential site locations should receive a compensation package for the use of land consistent with Afghan law.

In March 2005, communication was opened with the ADB to confirm the scope and timing of well field rehabilitation works contemplated to be funded by the ADB. AEAI was invited to coordinate activities with ADB's technical advisors. During March, ADB representatives held meetings in Kabul with MMI and Afghan Gas to discuss the power project, including discussions on how to deal with sulfur removal and how the ADB funding cycle relates to the development schedule for the power plant.

In April 2005, after the initial site visits and the determination of initial findings, USAID requested a series of meetings regarding the Sheberghan Project to ensure ongoing communication with all stakeholders. The first of these meetings was with the Power Donor Group Co-ordination group and was held at the MEW on April 26, 2005. Attendees of this meeting included representatives and technical advisors from the MEW, including the Project Implementation Support Unit (PISU); MMI advisors; ADB staff and technical advisors; KfW, USAID representatives and technical advisors; the World Bank; the Indian Embassy; the Iranian Embassy; and the Government of Japan. The meeting covered donor planning affecting the entire power sector, including the Sheberghan Project. Selected points discussed were:

- Project and feasibility study processes (outlined by the USAID representative)
- Main issues such as gas supply, power transmission, and plant location
- Different technical structures (i.e., an integrated project or separate gas and power projects)
- Refurbishment of wells (ongoing work by ADB)

On April 30, a follow-up meeting was held. Attendees at this meeting included representatives and technical advisors from the MEW, USAID, the World Bank, and the ADB. At this meeting, the following points were discussed:

- Power production is a high economic use of gas (an “anchor tenant”).
- Sheberghan gas is currently being provided to about 30,000 domestic customers and the fertilizer plant at very low prices, but most services are not paid for.
- Because of the importance of gas pricing principles, the World Bank will hold a workshop on these principles in May.
- Depending on the USAID program, the World Bank may consider financing or co-financing parts of the NETS and the Sheberghan Project.

Following these meetings, AEAI completed a draft of the gas assessment and circulated it for review in May 2005. A draft of the overall feasibility study was completed in June 2005, and the results were presented to ministers, senior staff, and technical advisors of the MMI and MEW, and to USAID and US embassy personnel on June 19, 2005 at the MMI.

From July 7 to 13, 2005, technical coordination meetings were held to review the draft feasibility study and to firm up the various recommendations and decisions resulting from the prior workshops and studies. The objectives of these workshops were (1) to bring together all parties interested in the development of the Sheberghan Project and provide a platform for receiving feedback; (2) to review the draft feasibility study, assess all technical requirements, and agree on all technical issues to ensure successful development of the project; (3) to identify any missing elements that may require additional funding, and; (4) to discuss the presentation to potential donors for their consideration. Attendees at these meetings included representatives of the MMI, DABM, USAID, ADB, and AEAI.

Key results of these meetings, as excerpted from the meeting minutes, are presented below:

- Project scope—all technical issues need to be listed, addressed completely, discussed, and resolved. Any funding gaps identified will need a proposal prepared for submittal to donors for funding. Information obtained from meetings and field visits are to be incorporated in the final feasibility report.
- Project business components
  - All parties agreed that formal agreements should be developed between the MMI and MEW to cover the supply of gas from the MMI to the MEW, and the supply of waste heat and power from the MEW to the MMI.
  - No GoA policy changes are required to develop the agreements.
- Project location
  - A presentation was made about the site selection process, the criteria for selection, and a review of six different possible sites in the Sheberghan and Mazar-e-Sharif regions. It was agreed that the proposed Gerquduq site best met all criteria.
  - The decision that the plant be sited at Gerquduq received unanimous approval.
- Plant sizing
  - For reliability of the NETS, the plant should be installed using multiple units of no more than 20 MW, which is ±5% of the expected 400 MW power demand in the NETS. It was clearly recognized that this precludes consideration of using larger scale gas turbines at Sheberghan.

  - A nominal 100 MW project consisting of units of no more than 20 MW was agreed to by all present at the meeting. Further, it was agreed that the plant should be designed for future expansion, pending further development.
  - The nominal plant size is consistent with the initial sizing proposed in the Master Plan.
- Technology selection
  - All agreed that the tender will be based on a performance specification and that no specific technology would be dictated. Responders would be allowed to propose any proven technology that can best satisfy stipulated technical and economic performance requirements.
  - There is uncertainty about whether or not sufficient water supply exists for water intensive technologies (certain combined cycle configurations employing evaporative cooling systems). Further, discussions addressed the need to consider "best use" for available water as a scarce resource.
- Current and future required gas supply
  - As a result of updated information gathered by AEAI on field trips to Sheberghan, a group of wells was chosen as potential candidates for remediation.
  - ADB reviewed its gas field remediation program and stressed that there is no budget for drilling new wells.
  - It was noted by ADB representatives that MMI has independent flexibility to decide what to do in terms of any needed requirements for rehabilitation.
  - A formal request for gas supply for the Sheberghan Power Project should be sent from the MEW to MMI.
  - There was a discussion about the timing and cost of a gas field remediation program for various fields and wells. MMI stated that they will develop a remediation and supply enhancement program to supply the power plant.
- Gas quality requirements—Basic information on gas quality and characteristics needs to be reassessed in order to develop a more detailed basis of determining potential gas processing needs. Gas quality specifications required for the power plant will be sent to ADB technical advisors.
- Budget estimates
  - USAID's plan is to fund up to US $150 million for the power production and gas treatment portion of the overall project.
  - ADB's budget for gas field remediation needs should be discussed so any funding gaps may be adequately covered.

During September and October of 2005,[2] the study team held a series of focused, high-level meetings with the MMI regarding gas supply, which is perhaps the most critical issue for the project. Detailed plans were established for supplying gas to the power plant. Attendees included MMI officials and technical advisors and USAID. Specific agreements and understandings emerging from these meetings included the following:

- The first step to memorialize the understanding about gas supply should be a "heads of agreements" between MEW and MMI; this should serve as a prelude to a formal contract.

[2] Meetings were held on September 5, 8, 10, 11 and 12 and October 12, 16, and 17.

- The signing of the ADB loan documents is the ultimate authorization for the MMI to undertake a gas development program as it sees fit; no further approval is required from ADB.
- Specific gas fields and wells were discussed at length. This discussion included establishing what fields and wells were off-limits for supply to the power plant, and which specific wells could be rehabilitated and dedicated to supply the power plant (see Annex 3 of the main report).
- Procurement of the required drilling rigs was discussed, with specific discussions about whether to buy or lease rigs. It was agreed that speed of mobilization should be the deciding factor. A priced scope of work for well field remediation was set forth in detail and submitted to the MMI.
- A full remediation plan, including specifications and scope of work, was prepared and presented to the MMI.

As of November 2005, the project team completed the collection and assessment of information for this feasibility study. AEAI believes that all stakeholders' issues identified have been considered and reflected in this study. Although it is possible to further refine the feasibility assessment, AEAI believes, that for a project at this stage of development, it would not materially add value to the decision-making process, nor would it alter any of the basic decisions made to date to continue this phase of the project.

OVERALL CONCLUSIONS

The Project, as outlined and assessed, appears to be an excellent opportunity to gain high-impact results that are consistent with the mission of USAID and other donors in Afghanistan. The main conclusions of the feasibility study are:

- There are sufficient indigenous gas reserves, both proven and highly probable, to fuel the 100 MW power plant for its 20-year design life. Confirmation of these reserves is a necessary priority.
- The infrastructure related to accessing the indigenous gas reserves (wells, piping, gas treatment systems, etc.) will require significant remediation work. A suggested plan for this work is included in Annex 3 of the main report.
- The price of gas is an issue that must be resolved to ensure long-term economic sustainability to the gas supply sector. The price should be set at a level that will attract needed private investment in further gas exploration, infrastructure development, and production facilities to encourage future expansion.
- For the purpose of the analytical requirements of the feasibility study, and consistent with existing proposals of international donors as agreed upon by the MMI, the gas price was assumed to be in the range of US $2 per GJ (details are in Annex 9 of the main report). It should be stressed that this price range is for analytical purposes only, and does not constitute a recommendation for gas pricing.
- The power plant site will be located at Gerquduq, which is near the city of Sheberghan in the vicinity of the existing DABM substation and the Afghan Gas Company well fields and processing facility.
- The project will be supplied with water from the pumping station at Qarakent, which is designed to draw 2,000 m^3/day. An open cycle configuration utilizing gas engines or gas turbine technology will require a total water requirement of approximately 10 m^3/day. In a combined cycle configuration with a dry cooling system, the total water requirement

ranges between 147 m^3/day to 215 m^3/day using gas engines and gas turbines, respectively. However, in a combined cycle configuration with a wet cooling system the total water requirement increases significantly to 1,100 m^3/day using gas engines and 2,100 m^3/day using gas turbines. Refer to Annexes 6 and 7 of the main report for details.

- The best equipment configuration for the 100 MW electric power plant appears to include a number of gas-fired reciprocating engines. Contractors may offer any gas-based technology such as reciprocating engines or gas turbines, with or without a steam cycle utilizing dry cooling with an air-cooled condenser. Dry cooling is used where there is a shortage of water (refer to Annexes 6 and 7 of the main report for details).

- Both engines and turbines are reliable, modular, power-efficient, require a minimum amount of water, and are relatively fast to install. Engines appear to be able to achieve a lower up-front installation cost and, in this application, a lower maintenance cost. However, it was agreed that tenderers may propose any equipment configuration, and that all configurations will be assessed during the tender evaluation process in a transparent fashion.

- There will be a competitive tender to design and build the project. The specific technology to be utilized will be determined by the best value selection resulting from the tender. Within this framework, the tender will contain specific performance requirements. The equipment will need to be economical, of a proven technology, reliable, easy-to-operate and maintain, modular in design, efficient to operate, require a minimum amount of water, and relatively fast to install. *The MEW, with USAID assistance, will evaluate the offers for proposed electric energy plants on the basis of economics, delivery, flexibility of operation, past equipment performance, and predicted reliability. Any technology proposed in response to the tender, provided it meets all of the performance criteria, will be welcomed* (see Chapter 4 and appendices Q and R of the main report).

- As assessed in this study, the capital cost of the 100 MW power plant is expected to be in the range of US $110 million. The gas conditioning plant (which includes upgrading a small water pumping station) is expected to cost approximately US $35 million . The remediation of the gas fields is expected to cost about US $25 million. It should be noted that these projected costs are based upon an analytical estimation, and not the results of tenders. The realized costs are not expected to exceed the estimation, and the competitive tender may result in materially lower capital costs.

- It is assumed that USAID will fund the construction of the power plant and the gas conditioning plant. It is anticipated that the MMI will fund the remediation of the gas fields and associated gas gathering systems from other available funds. USAID and all other donors will coordinate the implementation of this project and the necessary interfaces.

- A technical and economic assessment was carried out to estimate the total price of electric energy, including capital costs, fixed and variable operations and maintenance (O&M), and fuel price as indicated above. This total price, based upon analysis (see Annex 9 of the main report) is expected to be approximately US $0.05, at the high side of the plant transformer. If the initial capital cost of the power plant is financed on a grant basis (i.e., there is no recovery of initial capital cost), then the operating cost of delivered wholesale electric power is expected to be in the range of US $0.03 per kWh.

- The Sheberghan Project is justified, vis-à-vis other power supply options, because it is the least-cost and fastest option that could be put in service for units of this size. The economic assessment (Annex 9, main report) shows it is the most reliable and most flexible option, and that it provides a component of critically needed system stability to

the NETS. The expansion and extension of the reliability of electricity provides a basis to enhance the national socioeconomic stability and development.

- It is recommended that as part of the competitive tender to design and build the Project, the plant will be placed under an O&M contract with an operating entity that is highly experienced in the technology ultimately selected by tender. It is further recommended that the entity selected should provide O&M under contract through the first major overhaul. Twinning (i.e., having Afghan personnel work side-by-side with expatriate advisors) should be a requirement of the contract for capacity-building purposes.

GAS-TO-POWER ASSESSMENT

The assessment of available and potential gas to supply the proposed plant (see Annex 3, main report) was carried out to review and confirm the projected available fuel supply as it applies to current uses and the additional requirements for the Sheberghan Project. This was done by considering available existing gas supply data, including gas supply, quality, and pressure and the cost of remediation and additional facilities.

The feasibility study team reviewed prior analyses by various experts, made multiple site visits, and held multiple discussions with long-term field managers from MMI's Afghan Gas. A gas field remediation program was outlined and a cost estimate was prepared, though of course, the actual costs or quantity of gas realized cannot be guaranteed prior to field work. Nonetheless, through prior experience, the joint assessment by Afghan Gas and the feasibility study team indicates that there is a high probability of achieving the required supply without impacting current domestic gas use.

The main conclusions of the gas assessment are:

- There is enough gas to power a nominal 100 MW power plant for its design life, and at the same time there is sufficient gas to serve the existing customers while also serving a significant number of new residential and small commercial customers.
- The cost for remediation of the gas fields necessary to serve the power plant is expected to be relatively modest, in the range of US $25 million.
- The timeframe required to bring the overall facility fully on-line, is fairly short, about 17 months.
- The project offers an opportunity for significant employment and capacity building.
- The project offers a best option potential for the development of a long-term anchor gas customer.

ENVIRONMENTAL IMPACT

The purpose of the environmental impact analysis (see Annex 8, main report) is to make a comprehensive assessment of all environmental impacts of the project including impacts related to air, water, land, transportation, employment, and social issues.

The Sheberghan Project (including the gas conditioning plant) will result in only minor and acceptable environmental impacts. Key environmental mitigation measures based on international best practice in the design, construction, and operation of thermal power generation facilities have been incorporated into this Project and are reflected in the Environmental Management Plan, such that there will be no unacceptable environmental impacts arising from the Project.

Potential air quality impacts will be minor and acceptable due to the following factors:

- Natural gas is relatively clean compared to other fossil fuels used for thermal power plants.
- High-efficiency equipment will be used to reduce the amount of CO_2 per unit energy of electricity produced for the technologies under consideration.
- Cogeneration between the power plant and the gas conditioning plant could reduce the amount of CO_2 per unit of electricity produced further than if the electricity was produced separately.
- The site has good air shed characteristics that include exposure to prevailing winds that are directed away from sensitive receptors, lack of air inversions, and distance from populated areas.
- If gas engines are used, they will be tuned for later fuel injection timing (selective non-catalytic reduction) to ensure World Bank NO_x emission limits are met.
- Stack emission heights will be designed according to good engineering practice.
- Incineration of the acid (H_2S) gas stream following gas conditioning will result in emission of SO_2 levels that are well within the World Bank emission limits. This avoids the need for expensive sulfur recovery and potentially problematic sulfur disposal processes, or alternatively, for reinjection of acid gas into a spent gas well. If a productive use of the sulfur can be identified in the future, then the incineration process should be reconsidered.

Potential impacts on water resources and water quality are likely to be minor or insignificant, due to the following factors:

- There is little reliable quantitative information available regarding groundwater resources in Sheberghan. This limited data is from the Afghan Gas Company's Qarakent pumping station. The Qarakent groundwater pumping station is located in the lower Sarepul River valley about 10 km south of Sheberghan. It originally provided water from 12 wells for both the Gerquduq and Khoja Gogerdak gas treatment plants as well as for domestic supply of Afghan Gas Company employees at a rate of about 1,500 m^3 per day (designed for 2,000 m^3 per day). The gas treatment plants have not been operational for many years and currently only two water wells at Qarakent are operational. It should also be noted that the need for integrated water resource management to balance competing demands such as domestic and agricultural use is a key priority for the country. Based on the above, the power generation and gas conditioning technology has been selected to minimize water requirements and therefore minimize potential impacts associated with conflicting water uses.
- On-site treatment or management of potentially polluting discharges will be implemented including containment facilities, grease and oil traps around areas draining workshops and fuel storage areas, and septic tanks for sanitary waste.
- An impermeable evaporation basin will be provided near the site for the disposal of wastewater.
- Procedures will be established for the safe storage, handling, transport and recycling of waste oil according to international "best practices."
- Appropriate buildings and facilities will be established for the on-site storage of oils, fuels, and chemicals. These will include spillage containment measures, firefighting, and clean-up facilities and procedures, all in accordance with international best practices.

There will be no need for land acquisition and subsequent population resettlement since all Project land is currently owned by the MMI.

Significant socioeconomic benefits will accrue from the Project including:

- Economic benefits through employment creation—90 long-term, fulltime local jobs during the 20-year operation and maintenance period, and a much larger local labor force during the initial two-year construction period
- Skills transfer and development opportunities
- Stimulation of service industries
- Socioeconomic benefits associated with improved electricity supply

Full implementation of the Environmental Management Plan and Environmental Monitoring Plan, supported by the proposed institutional arrangements for environmental supervision and training, will ensure that the residual environmental impacts of the Sheberghan Project will be acceptable.

SITE SELECTION

Development of the generation facility is based on utilizing the natural gas resources in the Sheberghan area. Consistent with the Norconsult Master Plan, potential sites for the power project were restricted to the Sheberghan / Mazar-e-Sharif corridor in the Balkh region. A general assessment of the Sheberghan to Mazar-e-Sharif area was made in the context of required project inputs and costs including economic, social and environmental impacts.

Selection elements for site evaluation purposes (as outlined in Annex 5 of the main report) were compiled by the feasibility study team before mobilization to the study area, based on previous experience and a preliminary “desk study” of the region. The selection elements for more detailed site evaluation purposes fell under 12 assessment categories as indicated below:

- Land availability and suitability, topographical, and meteorological considerations
- Electric transmission grid connection considerations
- Water supply
- Fuel supply
- Construction cost factors
- Factors influencing the provision of civil facilities and site development
- Environmental considerations
- Social considerations
- Safety and security considerations
- Operations and maintenance
- Risk considerations, such as location risk for exporting power
- Economics inclusive of construction and ongoing O&M

After applying the above criteria, six potential sites were considered in depth. Four were in the Sheberghan area and two were in the Mazar-e-Sharif area, as follows:

- Site 1, at Gerquduq in the vicinity of the existing DABM substation and the Afghan Gas Company well field and processing facility
- Site 2, at Khoja Gogerdak adjacent to the Afghan Gas Company well field and processing facility
- Site 3, at Qarakent, in the vicinity of the existing water pumping station, which supplies potable water to Sheberghan City and the Afghan Gas Company assets at Gerquduq and Khoja Gogerdak

- Site 4, on the eastern outskirts of Sheberghan City, on land identified as a potential industrial zone
- Site 5, adjacent to the MMI fertilizer plant at Qala Jangi, near Mazar-e-Sharif
- Site 6, adjacent to the existing DABM substation at Mazar-e-Sharif

A detailed site scoring analysis was performed to determine how each of the potential sites ranked, using an industry-accepted practice called multi-criteria analysis (MCA). Annex 5 of the main report provides the full details of this assessment. MCA is a technique of project appraisal that takes into consideration more than one criterion when evaluating alternative projects or project-related decision making. The main goals of the MCA technique as applied to this study are to (1) yield a preferred power plant site, (2) assist the study team members in articulating and applying professional judgment to the site selection process in a rational and consistent manner, and (3) document the process. MCA is used to assist in the decision-making process of funding agencies such as the World Bank and the ADB.

The outcome of the MCA site selection process is as follows:

- The Gerquduq site is ranked first consistently.
- The Khoja Gogerdak site is ranked second consistently.
- Other sites consistently ranked in positions 3 through 6.

The following summary table indicates the combined weighted score resulting from the site selection. This information provides the relative preference of the sites in comparison to one another.

SITE SELECTION WEIGHTED SCORES

SITE	SCORE
Site 1—Gerquduq	40.75
Site 2—Khoja Gogerdak	34.35
Site 3—Qarakent	30.61
Site 4—Eastern outskirts of Sheberghan City	31.48
Site 5—Fertilizer plant near Mazar-e-Sharif	30.04
Site 6—DABM substation Mazar-e-Sharif	28.28

Some parties have questioned the potential placement of the Project in Sheberghan as opposed to Mazar-e-Sharif, Pul-e-Khumri, or even in Kabul. In this study, the prescreening of sites was driven by the need to (1) optimize the use of available financial resources which have competing demands in the rehabilitation of the power sector in Afghanistan and (2) select a site where implementation can take place within a relatively short-term timeframe. This is required to meet GoA’s goal of adding additional power supply in the short- to mid-term timeframe. Because of cost and time constraints, potential sites had to be near gas fields and the power transmission grid, criteria that were also recommended in the Power Sector Master Plan.

In accordance with all criteria assessed and as noted in Annex 5, it is concluded that the best realistic choice for location is in the Sheberghan area.

POWER PLANT ALTERNATIVES

Various technical configurations for the power plant and the gas conditioning plant were considered (see Annex 6, main report), each of which considered the following constraints:

- Natural gas pricing from the wellhead is based on projected gas field remediation cost and relevant MMI regulation.

- Based upon expert assessment and discussions with stakeholders, it was determined that the best option for fuel will be from the Gerquduq Jurassic gas formation, within the range of 0.18% to 1.7% of H_2S.
- The design should maximize the reuse of the existing Gerquduq field pipelines and gas gathering systems.
- Reserve gas supplies will be from the Yatimtaq field via existing pipelines.
- Minimal generation capacity throughout the whole of Afghanistan and unit sizes result in electric network stability problems for large-scale generating units.
- Limited water in the region places a premium on minimizing water usage.
- Water pricing for supplies from the Qarakent substation is based on regional water values.
- The site will have a relatively high elevation with large swings in ambient temperature.
- There is no current thermal load at the Gerquduq site other than for gas conditioning.
- Emission levels for NO_X and SO_X are based on World Bank standards.
- Transport of equipment will likely be via over-the-road through Uzbekistan.

Gas delivered to the power station is planned to be stripped of H_2S gas using an amine process, and water will be removed using a glycol process. The acid gas stream from the amine process will be incinerated, while meeting World Bank emissions guidelines. These are all standard processes that are widely used in the gas industry.

A preliminary technical and financial evaluation of generation technologies was undertaken to determine the various technical configuration options that could satisfy system needs and the performance requirements of the system within the constraints of the site. In this process, a preliminary assessment of the most cost-effective technology, based on the above site constraints, was also undertaken. The result of this analysis is being used internally only for planning purposes.

Equipment options considered for the power plant alternatives were constrained by technical issues, which were discussed in detail at the technical coordination meetings held on July 7 and July 10, 2005. One issue is the total size of the Project. It was agreed at this meeting that an initial 100 MW block of added capacity was needed, with individual units of a maximum size of 20 MW. It was also agreed that as the electric system and gas supply development expand, future consideration should be given to expanding the capacity of the plant.

Another technical issue is that the unit generation size needs to be small enough to flexibly respond to system load fluctuations. For planning purposes it was assumed that the NETS system would have a peak load of 400 MW. For reliability and management, the power plant will be made up of several generation units, totaling 20 MW each. The industry accepted standard for unit size relative to system load is that one unit should not exceed 5% of peak load. As such, individual unit sizes are indicated to be no greater than 20 MW each.

Different types of technology were assessed. Depending upon the assumptions and operating regime applied, an open- or combined-cycle natural-gas reciprocating gas engine or gas turbine power generating station may have the lowest cost for delivered electric energy. Following discussions with the MEW and DABM, it was agreed that the selection of technology will be based on performance criteria and strictly determined by the tenders that are received as a result of the competitive tender.

The tender will require evaluation of equipment based on:

- Unit size for proper grid integration, reliability, and redundancy
- Proven technology
- Site weather and environmental conditions
- Cost of delivered electric energy—both capital and O&M
- Water use
- Plant operating efficiency
- Lead times for delivery and installation
- The ability to phase in generating capacity to meet future system growth
- Potential for the employment of local skills for maintenance of equipment, provided that the equipment is based on accessible technologies
- Efficiency gains by integration with the gas processing plant

ECONOMIC ANALYSIS

The purpose of the economic analysis (see Annex 9, main report) is to assess the post-construction, long-term financial, economic, and commercial sustainability of the Project. It is assumed that the capital costs of the power plant and the gas conditioning plant will be financed by international donors on a grant basis. Even so, in order to attract further private sector investment in the gas sector, it was assumed that the capital cost related to gas supply, which will be financed on a concession basis or on a grant basis, should be included in tariffs.

The projected price of power from the Project is based upon the power being available on a committed long-term basis. It is inappropriate to compare the committed long-term power price from the Sheberghan Project against the price of currently imported power available on a spot-market basis. Technical assistance is underway to help the GoA negotiate long-term committed imported power supplies and a competitive Sheberghan Project is a key tool in this negotiation. Further, the price of power paid to Sheberghan stays almost entirely within Afghanistan in the form of wages and government revenue.

Overall with respect to economic analysis, it is concluded that:

- The projected price of power from the Project, as defined and located, will be relatively low and affordable, around US $0.065/kWh for retail customers (including transmission and distribution cost). The expected bulk-supply price of power from the Project at the plant site is initially about US $0.03/kWh (assuming that the grant-based capital costs are recovered on a delayed basis).
- The power price contemplates full payment for natural gas and for power transmission and distribution. The power sector and gas sector in Afghanistan can be thereby commercially strengthened.
- This Project offers an opportunity for significant employment (90 long-term jobs) and capacity building (a second thermal power plant) during construction and operation of the power plant.

POWER AND GAS CONDITIONING PLANTS: ENGINEERING AND TENDER PACKAGES

The Power Plant Engineering Section of the feasibility study (Annex 7, main report) addresses two individual design/build tender packages: the Power Plant Engineering Package and the Gas Conditioning Engineering Package. The purpose of developing these packages was to provide a baseline for use in evaluating design/build tenders on a basis of cost and performance. The packages require the tenderer to provide detailed and comprehensive elaboration of all relevant technical considerations, with an emphasis on efficiency.

For the Power Plant Package, only one of several possible engineering designs was developed for this feasibility study, and that was for representative budgeting and planning purposes. At this stage in the project development process, the Power Plant Engineering is based on reciprocating engines due to the preliminary findings which indicate that they have the lowest installed cost per kWh for the lifetime of the project. *To reemphasize, either reciprocating gas engines or gas turbines in an open cycle or a combined cycle (with a dry cooling system) may emerge as better options from the actual tender process.*

The Gas Conditioning Package was developed considering all of the constraints and conditions of the preferred site and the fuel gas quality requirements. Based on these, the technology configuration was considered as follows:

- Simple knock-out vessel
- Amine scrubbing for H_2S removal
- Flaring of acid gas stream
- Glycol dehydration for dew point suppression
- Waste heat from the power station for amine scrubbing

The Power Plant Engineering section of the report contains the preliminary engineering, budget cost estimates, heat and mass balances, piping and instrument diagrams, layouts, outline specifications, control philosophy, and the project schedule for the above arrangements.

1.0 INTRODUCTION

This feasibility study report was prepared for the Ministry of Energy and Water (MEW) by Advanced Engineering Associates International (AEAI) under a multiyear contract in conjunction with the US Agency for International Development (USAID) as part of the Afghanistan Energy Assistance Program.

The work is governed by terms of reference developed by USAID, which may be found in Appendix A (Volume III) of this report. Upon completion and approval by MEW and USAID of the Report, the next step is to finalize, release and manage the competitive tender process, and award the Contract for the proposed facility. It is recommended that the Project be built under a turnkey engineering, procurement, and construction (EPC) contract that will also include an operation and maintenance (O&M) contract to operate the power plant through its first major overhaul period.

It is anticipated that the tender process will occur during the first/second quarter of 2006 with contract award in the second/third quarter of 2006. Construction of the project is expected to commence in the third quarter 2006, subject to confirming availability of gas supply.

1.1 BACKGROUND

Afghanistan is one of the least electrified countries in the world and, as a result, the lack of electricity restricts the development of all aspects of a normal modern life style. Due to the war with the Soviets, followed by internal civil war and the subsequent rule of the Taliban, the existing power system in Afghanistan has deteriorated steadily.

The Government of Afghanistan (GoA) and international donors have agreed that restoring and increasing the electric power supply is a top national priority. This is needed to support improved economic growth with resulting improvement in the standard of living. All parts of the power sector in Afghanistan are in need of capital investment, training, and capacity building in areas such as power generation, transmission, distribution, operations, maintenance, management, and electric system regulation.

The United States (through USAID) is planning to provide up to US $150 million to build a 100 MW gas-fired power generating plant and gas treatment plant using indigenous Afghan natural gas resources. There are natural gas fields around the city of Sheberghan, in northern Afghanistan that appear, subject to further well field testing and verification, to be sufficient to fuel such a power plant on a long-term basis.

1.2 ORGANIZATION OF THIS REPORT

The organization of this report includes (1) an outline of the desired objectives, (2) a description of the problems to be resolved and general constraints, and (3) identification of the regional context under which the work is to be performed. This is followed by AEAI's investigation, evaluation, analysis, and recommendations for proceeding with this proposed project.

The Executive Summary, presented earlier in this volume, briefly presents the overall findings, summarizes the overall efforts, and presents the conclusions and recommendations of the feasibility study.

Chapter 1, Introduction, provides the background and organization for this report.

Chapter 2, Project Rationale, demonstrates in detail why the project is important, worthwhile, and desirable.

Chapter 3, Project Development deals with unique development issues and discusses key foundational technical issues (high-level fatal flaw analysis of the core technical issues that need to be resolved before the power plant can proceed). The foundational technical issues are straightforward and focus on the following questions: (1) Is it likely that there are sufficient gas reserves in the Sheberghan fields to fuel the power plant on a long-term basis? and (2) Can the power be delivered to the customers identified in the project rationale?

Chapter 4, Project Tender and Construction, addresses the tender to supply equipment and to construct the project: it describes the proposed plan for going out for tender and the required performance of the proposed power and gas processing plants, and outlines how the tenders will be evaluated.

More detailed technical and economic analyses are contained in the annexes to this study found in Volume II. These include the Gas Assessment (Annex 3), Data Collection and Interviews (Annex 4), Site Selection (Annex 5), Power Plant Alternatives (Annex 6), Power Plant Engineering (Annex 7), Environmental Impact Assessment (Annex 8), and Economic Analysis (Annex 9). These analyses more tightly define the Project on key parameters such as how big the plant might be, where it should be located, and what type of equipment is required.

The Economic Analysis Annex (Annex 9) contains an estimate of all the costs necessary to implement the power generation portion of the project, including the cost of producing the gas for power generation.

2.0 PROJECT RATIONALE

Afghanistan has an insufficient amount of power supply resources relative to its population: only 215 MW of operable installed capacity is available for 23 million people—one of the lowest levels of electrification in the world. To put this in perspective, Figure 2.1 shows the electrical capacity of various emerging market countries.[1]

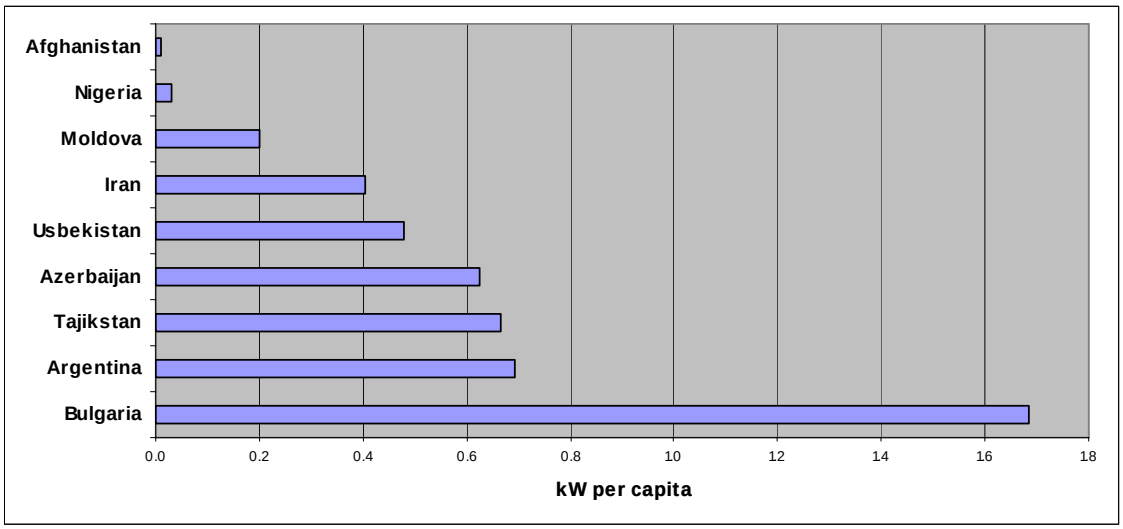


Figure 2.1 Power Supply per Capita in Selected Emerging Market Countries

As noted in the Introduction, the lack of electricity is recognized by GoA and international donors as a priority issue. In most areas of Afghanistan, potential customers wait months to get an electrical connection, while power shortages and load shedding are frequent occurrences for connected customers. Furthermore, in order to have any reasonable and hopeful level of economic growth, new power supplies are needed. An estimate of future power demand is shown in Table 2.1.

For purposes of discussing the power sector in Afghanistan, Norconsult divided the country into eight regions, as shown in Table 2.1: Kabul, Nangarhar, Parwan, Ghori, Balkh, Herat, Kandahar, and Other. The NETS will interconnect Kabul, Nangarhar, Parwan, Ghori, and Balkh. The Sheberghan Project is intended to serve demand in Kabul, and the northeast region, including Nangarhar, Parwan, Ghori, and Balkh.

The Sheberghan Project, as part of NETS, will have a significant role in meeting demand in these regions, including Kabul. In 2008, when the Project is scheduled to be completed, total peak power demand in Afghanistan is expected to be 461 MW, as shown in Table 2.1. Peak demand in Balkh in 2008 is projected to be 83 MW. Thus, the Sheberghan project may completely serve demand in the north, such that after the NETS is completed, CAR-country imports may go to help meet demand further south along the NETS and in Kabul. For power system stability, it is essential to have some appropriate amount of local generation serving local load. Without the Sheberghan plant, there is virtually no local generation in the north.

[1] U.S. DOE Energy Information Agency

TABLE 2.1 SUMMARY BASIC PEAK LOAD FORECAST FOR AFGHANISTAN (MW)

SUMMARY	KABUL	NANGARHAR	PARWAN	GHORI	BALKH	HERAT	KANDAHAR	OTHER	TOTAL
Present load	111	8	2	14	38	2	30	10	215
Suppressed demand	55	5	6	12	13	8	12	10	121
Forecast basis	166	13	8	26	51	10	42	20	336
2003	152	13	8	26	54	12	40	20	326
2004	157	14	9	28	60	16	40	22	347
2005	169	16	11	31	66	20	41	24	379
2006	182	19	13	37	72	25	43	27	418
2007	185	21	14	39	78	29	44	29	439
2008	187	23	16	42	83	33	46	32	461
2009	194	25	17	44	87	35	48	34	485
2010	200	27	19	46	91	37	51	37	507
2011	205	29	20	48	95	39	53	39	529
2012	219	32	22	51	101	43	57	42	567
2013	234	34	24	54	108	47	60	45	606
2014	248	37	25	58	113	50	64	48	644
2015	263	40	27	61	120	54	68	51	683
2016	279	42	29	64	126	58	72	54	724
2017	295	45	31	68	133	62	76	57	766
2018	312	48	33	72	140	66	80	60	811
2019	329	51	36	76	147	70	85	63	857
2020	347	54	38	80	155	74	90	67	905

Source: Ministry of Water and Power Afghanistan 2004, Power Sector Master Plan. Prepared by Norconsult under World Bank AFG/03170.

All power sector planning for Afghanistan has assumed that the Sheberghan Project will be completed as soon as possible. (Also, due to the timing of completing the NETS, and the resulting total demand in the entire NETS region, there is a need for the entire 100 MW to come on-line in 2008, as discussed below.) The Power Sector Master Plan (Norconsult, 2004) depicted the Sheberghan Project to be completed in two 50 MW phases, at a cost of about US $125 million; AEAI's analysis indicates the plant costs can be cut to about US $110 million by building the 100 MW all at once. This is due mainly to the savings resulting from mobilizing construction resources only once instead of twice.

The Sheberghan plant will provide power to serve demand in the entire NETS area in 2008, about 337 MW (the sum of forecast demand in Kabul, Nangarhar, Parwan, Ghori, Balkh, less the demand in Herat, Kandahar, and other areas). The totality of the Sheberghan Project and imports from the CAR countries will serve demand in the northern, northeastern, and Kabul regions. The Master Plan shows the Sheberghan Project as comprising the bulk of the power supply in Balkh region, as shown in Figure 2.2.

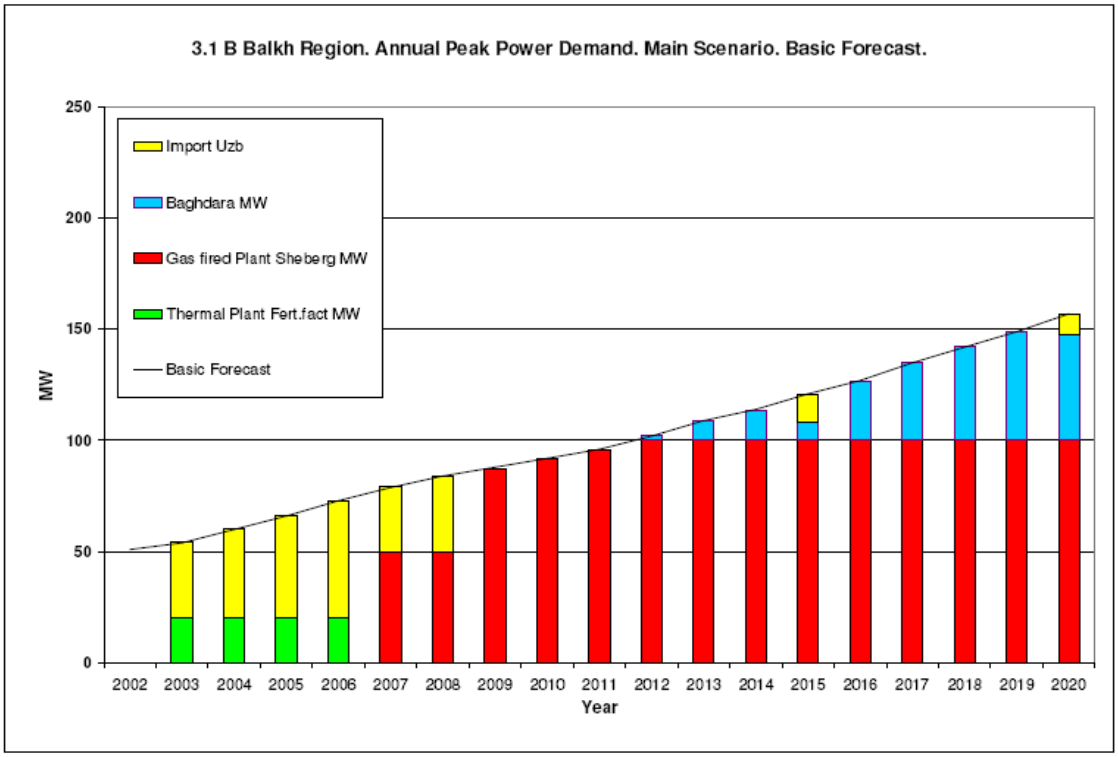


Figure 2.2 Projected Power Demand and Supply in the Balkh Region
Source: Ministry of Water and Power Afghanistan 2004, Power Sector Master Plan. Prepared by Norconsult under World Bank AFG/03170.

2.1 REGIONAL CONTEXT

Afghanistan is bordered on the north by the Central Asian Republics of Tajikistan, Uzbekistan, and Turkmenistan. Currently each of these countries provides, as available, electric energy in limited amounts to Afghanistan under short-term agreements. These countries have offered the possibility of firm, long-term power exports to Afghanistan, while recognizing that Afghanistan may serve as a “transit country” for broader wholesale electricity trade in the south Asia region.

At present, none of the existing international connections allow supply from outside Afghanistan to reach the main load center of Kabul. To accomplish this, a major internal transmission project, the North East Transmission System (NETS), is underway. The Sheberghan Project is a critical component of the NETS. The fundamental purpose of the NETS is to broaden the base of electrical capacity from which Afghanistan can be most economically supplied. A diagram indicating the major transmission components of the NETS is provided in Figure 2.3.

Under a reasonable set of assumptions regarding the capital costs and operating expenses for the Sheberghan Project, it is likely that the total cost of power on a fully accounted basis could be higher than the price of power potentially offered by CAR countries. A legitimate question is: Why build this project if less costly supplies may appear plentiful?

There are powerful reasons that this plant is needed, despite the claim of alternative more economical regional sources of power supply. The estimate of regional power surplus is based on limited information about Soviet-era, partially built power plants, and/or power plants in an unsubstantiated state of good repair. Consider the following statement by ADB made at the 19th World Energy Congress, Sydney, Australia September 5–9, 2004:

> “Hardly any investment has been made in the region since 1990. The infrastructure in general is old, for example, the interconnections of power and natural gas [transmission

pipelines] were built around the mid-1980s and then there are the large hydropower stations in the Kyrgyz Republic (early 1980) and Tajikistan (early 1970). The metering infrastructure for both electricity and gas needs rehabilitation to properly measure cross border flows . . .. The region needs large immediate investment for the refurbishment and rehabilitation of its network (gas pipeline and power grids), gas production and power generation projects. With the current financial situation most countries are unable to finance these projects. There are some partially completed large projects, which would also provide the cheapest alternative forms of energy for the region, but these can only be justified if their output is exported . . .”

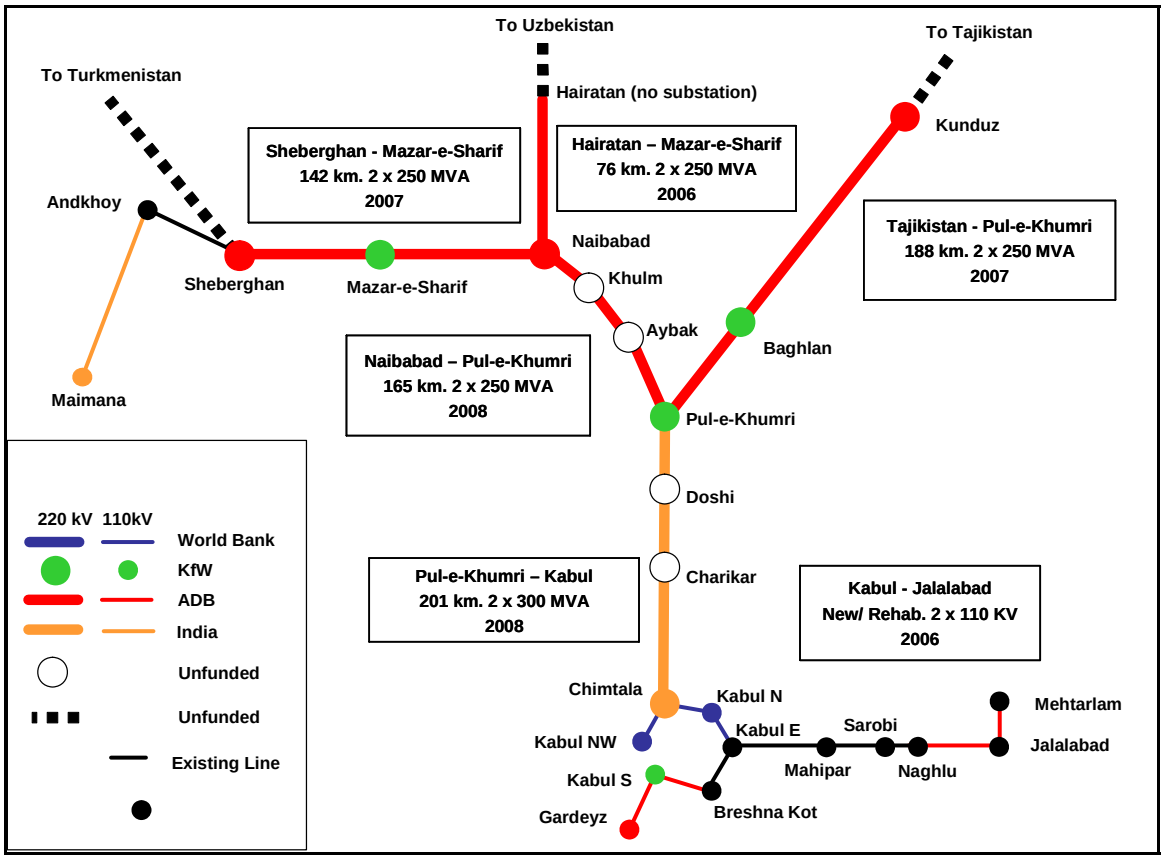


Figure 2.3 North East Transmission System

Secondly, the CAR countries lack “. . .capable institutions (policymaking, planning, regulation, technical standards, etc.) that form the basic building blocks for a fully functioning regional energy market. These institutions will provide a consistent framework for transparent decision-making, repeatability and predictability of regulatory procedures, and an enabling environment for investing in multi-country projects by both private and public sector investors. The Central Asian region lacks these institutions.”[2]

Thirdly, it should be noted that the Sheberghan power plant is a committed resource with a long-term, fixed-price cost structure. It is not possible to create a 2025 year power contract with any of the CAR countries that is, on a risk-adjusted basis, comparable to Sheberghan. The on-going donor-funded international capacity-building program to encourage low-risk, long-term power sales agreements between Afghanistan and the CAR countries is much needed. This program will continue to develop over the immediate future with the objective of evolving international standard, long-term, firm power purchase agreements. However, at present, the

[2] Hasnie, Sohail (ADB), 2004, *Challenges And Opportunities in Energy Trading in the Central Asian Region*, 19th World Energy Congress, Sydney, Australia September 5-9, 2004.

only currently written offers of power supply from the CAR countries are based on short-term floating prices. It is possible, though not preferable, to rely on short-term floating-price power contracts instead of long-term fixed-price contracts, but in a market where there are only limited alternative sources of power, the risk of doing so is extreme. Therefore, the proposed project offers additional leverage to Afghanistan as it pursues longer term power trade objectives with the CAR countries.

The Sheberghan Project is vital to provide Afghanistan with bargaining power when negotiating international power supply contracts. As witnessed by the California power crisis in 2001, when a power buyer has insufficient domestic power supply resources, they are at the mercy of outside sellers.

2.2 PROJECT RATIONALE SUMMARY

There are many operational advantages to a gas-fired power project in Sheberghan. These include:

- No import of expensive diesel fuel to operate the facility
- No use of scarce foreign exchange for imported power
- Maximized potential local employment
- Well-integrated generation capacity with seasonal hydropower—another indigenous Afghan resource and a potential source of power from Tajikistan
- Additional generation in the Sheberghan area, resulting in a stronger and more stable system for the NETS region and increased overall grid stability and reliability
- Economic competition to power sales from imports

In summary, proceeding with the Sheberghan Project is justified as follows:

- Afghanistan has a very low level of electrification; more domestic power supply is urgently needed. Without the Sheberghan Project, Afghanistan will have a generation power supply shortage for a minimum of 5–8 years until longer term planned hydroprojects are built. Without the Sheberghan Project, the shortage would be partially met by a combination of expensive and polluting diesel-generated power, and by imports priced for a sellers' market.
- While other options for near-term power supplies from imports are viable, as a sole source of supply, this is a risky strategy (without some domestic power supply leverage), economically and politically. Power shortages would impact the most vulnerable populations: those not able to afford stand-alone diesel gen-sets.
- The Sheberghan Project has key purposes relative to imports: (1) it is needed for grid stability (a minimum level of power supply in a "control area") and (2) it will provide Afghanistan with bargaining power in negotiating international power supply contracts.

3.0 PROJECT DEVELOPMENT

This chapter describes the issues and processes that have been and must continue to be considered during the development of the Sheberghan Power Project. Section 3.1 discusses two primary foundational issues, the assessment of the gas for use as fuel for the plant, and power transmission issues. The critical path for project development is provided in Section 3.2, while Section 3.3 presents issues related to the operation and maintenance of the plant after it is commissioned and turned over to the GoA.

3.1 FOUNDATIONAL TECHNICAL ISSUES

There are many complex technical issues relating to the feasibility of the Project, but two issues appear to be more technically fundamental than others. These fundamental technical issues relate to (1) information on gas reservoir conditions and (2) power transmission availability. These two issues, as compared to others, impart a special level of uncertainty and difficulty of analysis and prediction, and for these reasons they represent a fundamental impact on the feasibility of the Project.

The quantity and quality of the gas reservoir has been assessed using the best available information from existing field records. The information used has been assessed by various experts over the last few years and conclusions of each previous assessment has been compared in detail as part of the study carried out by the AEAI. The assessments, reviewed with available Afghan Gas experts, provide a reasonable basis to proceed. However, available data is predominantly secondary information with some primary but aged information. In order to fully proceed with the Sheberghan Project, new primary field information from well logging is essential. The costs of the gas field rehabilitation and production, which have been estimated using the best available information, will ultimately be a function of characteristics of the gas reservoir such as reservoir size, depth, pressure, gas composition, and other factors. Broadly speaking, the larger and better the gas field, the lower the cost of rehabilitation and production. The feasibility of economically making power at Sheberghan is very much dependent on the nature of the gas reservoir, which can only be effectively confirmed by actual quantification from rehabilitation.

There is a trade-off that is often made between transmitting power and transmitting gas. Quite often power facilities have, in various parts of the world, served as the anchor customer to justify building lengthy gas pipelines. Such an approach allows the further expanded use of gas for industrial, commercial, and—given the development of reticulation systems—residential use. As better information on actual gas reserves in the Sheberghan area is developed, evidence may show that gas volumes are large enough to justify the very significant investment that would be required to transmit gas via pipeline to major population centers such as Kabul. AEAI recognizes that there are different opinions about exactly where it is best to convert gas to power for evacuation by the NETS. Some have proposed developing a gas pipeline to Kabul and building additional gas-fired power generation in Kabul. Others support enhancing the gas pipeline to Mazar-e-Sharif, and building a power plant in Mazar-e-Sharif; however, enhancing the pipeline would require a basic complete rebuild of the pipeline, given gas pressure requirements for use in a power facility. AEAI's analysis, consistent with the Norconsult Master Plan, indicates the best technical and economic option to supply power into the NETS, from native resources within a reasonable timeframe of 24–30 months, is to locate the power plant on the gas field in Sheberghan. This requires the capability to evacuate the power from Sheberghan into the NETS, which, in turn, requires the development of the 220 kV transmission line from Sheberghan to Mazar-e-Sharif currently being planned by the ADB.

3.1.1 GAS SUPPLY ASSESSMENT

The gas supply assessment was carried out by reviewing existing limited and aged primary information and available secondary information and by making a series of site visits that included interviews with local experts from Afghan Gas. As of the date of this feasibility study, MMI had not undertaken a detailed gas field physical testing program; however, the records and studies and interviews provided an adequate database to make tentative conclusions with sufficiently reasonable confidence.

The goals of the gas supply analysis were to:

- Review and verify currently available gas supply information including the capability of the known gas reserve base to supply the proposed plant configuration for its operating life.
- Verify in situ gas supply pressures and determine and cost any required compression facilities including a back-up compressor, if required.
- Assess available primary data on gas reserves and production potential, providing clear specification of the probabilities applicable to additional gas volumes expected to be available and the timeframe anticipated for their development.
- Develop the cost of production and the resulting price of the gas under current institutional ownership arrangements

The key conclusions are:

- There is enough gas to power a nominal 100 MW power plant for a design life of 20 years, and most likely well beyond that time, and there is enough gas to serve existing customers and a significant number of new customers.
- The cost of producing the gas is expected to be relatively modest.
- The timeframe to bring gas production on-line is fairly short—about 12 months.
- This Project offers an opportunity for significant employment and capacity building.

The production of gas required for 100 MW is approximately 0.19 bcm per year. Based on an in-depth review of all available information, it is recommended that, to fuel the power plant, well rehabilitation be focused on two gas fields in the Sheberghan area: Khoja Gogerdak and Yatimtaq. A third field, Gerquduq may be held in stand-by. The estimated production cost and the projected resulting amount of gas is shown in Table 3.1.

TABLE 3.1 SHEBERGHAN NEW GAS PRODUCTION COST [a]

FIELD	COST (US MILLION $)	P50 GAS RESERVES [b] (bcm)	TOTAL P50 GAS FROM WELL CANDIDATES FOR PROJECT (bcm)
Khoja Gogerdak	$11.4 million	13.6	5.0
Gerquduq	$6.7 million	3.7	3.7
Yatimtaq	$6.5 million	7.0	2.4

[a] This table shows only the cost of extraction, not including treatment. The gas from Khoja Gogerdak is the least expensive to extract, but it has the highest sulfur content, which makes it ultimately more expensive.

[b] P50 is a petroleum industry definition meaning that there is an equal likelihood of obtaining either more or less than the specified amount of reserves.

A detailed assessment of the gas for the Project is provided in Annex 3.

3.1.2 POWER TRANSMISSION

The Sheberghan Project is part of a comprehensive strategy to bring electric power to the NETS service areas, as noted above, including Kabul. The complete value added by the NETS requires a new transmission line to link Sheberghan into the NETS. It is expected that the line will also be required to import power from Turkmenistan.

The Sheberghan Project will export power to Kabul via the NETS. Parts of the NETS are in the process of being upgraded under ADB Loan No. 1977—Rehabilitation of the Northern Transmission Link—and also through a grant from the Government of India (GoI).

The GoI has taken responsibility to finance (up to US $111 million at current exchange rates) the construction of the transmission link from Pul-e-Khumri to Kabul. The GoI has tasked the Powergrid Corporation of India to manage the project. Powergrid officials undertook an in-depth study of the entire route, and in particular, the difficult passage over the Salang Pass. Given the difficulty of the terrain, it may seem that virtually any other alternative (other than the Sheberghan power plant plus transmission) might be preferable for supplying power to Kabul. However, projects to provide Kabul with other domestic sources of power generation have serious flaws.

For example, one suggestion is to build a power plant near Kabul. The fatal flaw in this alternative is that there is no fuel available near Kabul, which means that either coal, gas, or diesel would have to be imported. The cost of moving fuel is generally higher than the cost of transmitting power. The supply risk remains. Building a hydroproject of 100 MW would take, under the best of conditions, four to five years, whereas building the Sheberghan Project will take only two years.

The problem of building a transmission system to get power from Sheberghan to Kabul is not trivial. The system and route were studied by Powergrid, and this study was reviewed by the USAID, World Bank, and third-party experts. However, the construction is underway and at this point it appears that it will be successfully completed.

3.2 CRITICAL PATH OF PROJECT DEVELOPMENT

Project development involves many technical tasks which need to be performed according to an optimal critical path. As a matter of prudence, USAID—as would any rational investor—will wait to release funds for construction of this project until the gas quantity is confirmed by field work results.

Gas field logging and certain decisions from MMI will provide the following information to the prospective tenderers before a tender is issued. To date, this information has not been developed, although in a number of cases, such as those listed below, information development has been scheduled, or is being actively pursued:

- Testing and analysis of gas composition, pressure, temperature, and reserve confirmation must be performed after gas well reentry and logging.
- Analysis of the water from the Qarakent borehole needs to be performed.
- A reference gas price needs to be provided to power plant tenderers, in order for them to understand efficiency trade-off conditions, and to develop and optimize their proposals.

Gas composition information and water analysis is required before tenderers can price equipment, and is best provided in the tender documents rather than having the tenderers independently perform their own tests. As an alternative, a set of base assumptions can be made which all tenderers must use. The base assumptions can be provided using the results of this study.

The flowchart in Figure 3.1 shows the critical path sequences.

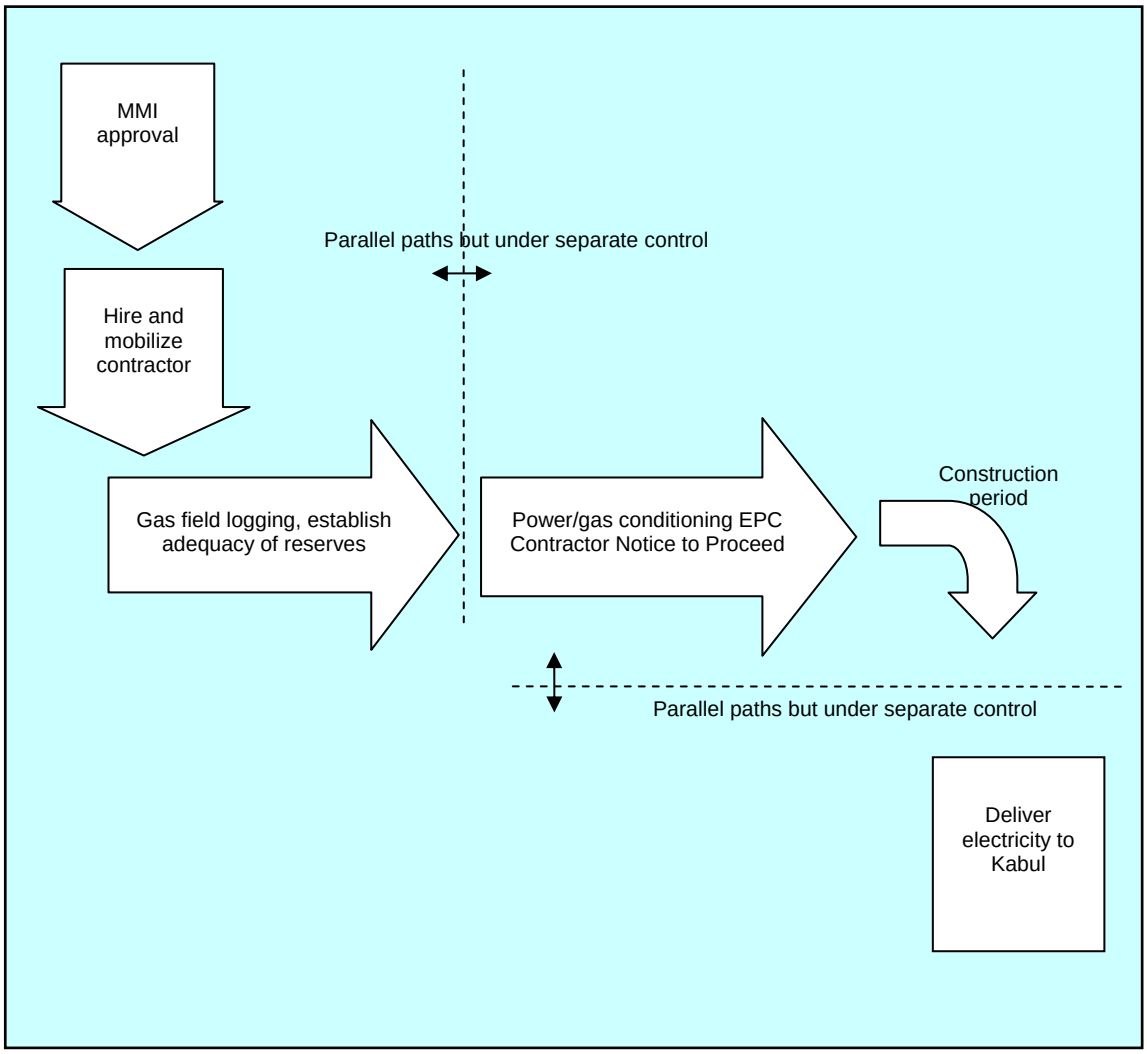


Figure 3.1 Key Critical Path Sequences

3.3 PLANT OPERATION AND MAINTENANCE ISSUES

A key project development issue is the O&M of the power plant after the construction period. Under USAID funding, the plant will be built and guaranteed to operate according to international standards. After the plant is turned over from USAID to the GoA, it must be operated according to international standards, or else the equipment vendor's guarantees will be voided.

Specifically, the construction contract will include performance guarantees and warranties that are predicated upon certain standards and practices being followed during the operation of the power plant (prudent utility practices). Performance guarantees and warranties are contractual promises made by the EPC contractor of the power plant that specify the minimum acceptable performance standards for the power plant. These standards relate to the output, performance, and efficiency of the power plant. Warranties are for performance during an initial period of operation, typically one year for large gas-fired power plants. In the event that the power plant fails to meet the minimum acceptable performance standards, the builder will pay damages to the project owner, as established in the contract

It is important that the designated standards and practices established by the contractor are understood and agreed to by the Afghan operators. Running the plant according to international

standards will be challenging because of the lack of depth in available local technical and commercial capacity.

It is strongly recommended that an O&M contract with specific training requirements be part of the tender for the plant. The contract should be for a sufficient period to cover the first major overhaul of the plant, following which local operations and maintenance personnel trained for the period can assume full control of O&M. As part of the EPC contract, during the first year of operation of the power plant the contractor is expected to provide all management, services, parts, and maintenance tasks necessary for successful operation of the power plant.

The EPC contract will include provisions for training Afghan O&M personnel on an off-site basis at a similar power plant. Also there will be training at the project site during construction. The builder will provide the appropriate operating manuals, procedures, and documentation necessary to operate the power plant.

Though the technical and economic features of the Project are critically important, the success of the Project is also a function of the Afghan national commercial, legal, and regulatory concerns. For other projects in Afghanistan, there are significant institutional issues that pose major obstacles to Afghan self-sustainability; these include the current lack of trained people in Afghanistan who can operate a modern, complex utility power plant. The institutional issues are many and complex and cannot be addressed completely in this feasibility study. The MEW and USAID should agree to develop and put in place a plan that will enable the Afghans to take over the entire project.

As part of the Project, it is recommended that USAID include the suitable training of local Afghans in the tender requirements in a way that allows the new owner to understand that performance guarantees and warranties could be voided for many reasons. These reasons include, but are not limited to, the following:

- Deviation from prudent utility practices[1]
- Use of improper fuel
- Failure to faithfully carry out O&M procedures
- Failure to document that O&M procedures were faithfully carried out
- Improper or inferior spare parts, or improper use of spare parts
- Loading the power plant with excess voltage, or allowing excessive fluctuating voltage

USAID has other requirements for the transfer of ownership. These include that the following conditions to be met before the contemplated transfer of the power plant can be finalized:

- Off-take conditions for power transmission are sufficient and safe for power plant operations.
- The proposed staff members are trained and appropriately compensated to carry out any and all needed works.
- Commercial arrangements are in place to create the budgeted levels of cash flow.
- There is a detailed and clear system for accounting and cash flow management so as to prevent improprieties.

[1] "Prudent utility practice" means any of the practices, methods, and acts engaged in or approved of by a significant portion of the electric utility industry during the relevant time period consistent with good business practices, reliability, safety, and efficiency, and practices generally accepted in a modern electric utility.

4.0 PROJECT TENDER AND CONSTRUCTION

The timeline for construction of the power plant and gas conditioning plant is dependent on the two foundational issues discussed in Chapter 3. Gas field logging is needed to firmly establish the expected gas reserves. The other key dependency is finishing the North East Transmission System so that electricity may be provided to Kabul. The project schedule contained in Appendix N shows these key sequences.

At the time this report was written, the complete well field rehabilitation program, construction of both the gas conditioning and power plant facilities, and the transmission system are all scheduled to be completed by October 2008.

4.1 TENDER

The gas conditioning and power production portions of the Project can be procured through a single overall contract, or through a number of specific EPC contracts. The challenge is to find the most appropriate method or mix for this particular project, taking into consideration the site, risks, schedule, and costs. A comparison of the advantages and disadvantages of each of these two different contracting approaches is summarized in Table 4.1.

TABLE 4.1 ADVANTAGES AND DISADVANTAGES OF CONTRACT APPROACHES

	SINGLE CONTRACT PACKAGE	MULTIPLE CONTRACT PACKAGES
Advantages	• Easier to manage from the owners' perspective • No contract interfaces • One party accepts all the project risk • Larger project more attractive to large international contractors • Some economies of scale for project	• Smaller contract packages are more attractive to smaller specialized contractors • Would tend to potentially attract regional firms interested in submitting tenders on specific portions
Disadvantages	• Premium placed on the tender price for the management and risk	• Contract interfaces need to be clearly defined and managed • Management / owners engineer required to supervise contracts • Increased risk of delay and variation claims • Smaller packages less attractive to large international contractors

Aid agencies and multilateral banks typically tend to prefer to prepare and manage one contract for all of the required works. The number of vendor lead contractors that would be willing to take on a single EPC project will be limited.

The number of funding agencies may influence the number of potential EPC tenderers willing to take on EPC contracts for all or only a part of the scope (i.e., tendering the power plant and gas conditioning plants separately may better suit specific donor funding agreements). In any case, the work for the gas conditioning plant should include the water pumping station upgrade. If a single contract package is used, both project plant packages will be handled by the same contractor.

USAID's portion of the overall Project involves two packages, as follows:

- *Power Plant Package.* This package consists of multiple generator units totaling approximately 100 MW, piping systems, and associated auxiliary plant including connection to the local Sheberghan substation, and the repair of a damaged 110 kV overhead transmission line. The 110 kV line repair between Sheberghan and Mazar-e-Sharif is included in this package so that power may be transmitted in the local region before the NETS is completed (see Section 5.2.2. of Annex 5 and Appendix Q). The contractor will also enter into an O&M contract for the overall operation and maintenance during the plant's first life cycle. Heat recovered from the power plant will be used for process heat in the gas conditioning plant.
- *Gas Conditioning Plant Package (including the Qarakent Water Supply Upgrade).* The Gas Conditioning Plant package includes the supply and installation of the process equipment and all work needed to construct the gas conditioning plant and the water pumping station upgrade to provide gas to the new power plant. The gas conditioning plant will be capable of processing the sour gas destined for the power plant.

4.1.1 SHEBERGHAN POWER PLANT PACKAGE

The work to be performed under the Power Plant Package includes the full works associated with the Sheberghan power station. This consists of the design, manufacture, inspection, and testing at the manufacturing facilities; packing for export or internal transport; shipment, customs clearance, delivery to site, unloading, and storage and handling at the site; complete erection and finish painting; testing and commissioning, performance testing, and handling trials; maintenance and supervision of operation during testing and commissioning; and warranty and inspection prior to final acceptance and training of local staff. The contractor will be obliged to enter into an O&M contract for the plant's first life cycle (i.e., through the first major overhaul).

The contractor will prepare a tender for a complete design, build, and commissioning of a power plant. The design will provide all information needed for the construction of the new Sheberghan Project. The plant shall be designed for continuous operation 24 hours a day, 7 days a week.

The technology to be employed may be either reciprocating gas engines or heavy duty gas turbines in an open cycle or a combined cycle using steam turbines with a dry cooling system using an air cooled condenser. Dry cooling is used where there is a shortage of water (refer to Annexes 6 and 7 for details). Site meteorological data and water requirements may be found in Annex 6. Selection of the successful contractor and technology to be employed will be based on set criteria. The intent is to construct a plant with the least cost per unit of energy delivered over the lifetime of the plant. To help drive the most economic generation philosophy, the contractor will also be obliged to enter into a contract renewable up to the first major overhaul for the plant.

The plant shall be sized for a total nominal output of 100 MW, measured at the high voltage side of the 110 kV step-up transformers, and for site conditions.

Each generation unit shall not individually exceed 20 MW, as the stability of the Afghanistan transmission system is insufficiently robust at this time to handle the potential instabilities created by trips from larger units.

The plant design shall be based on minimal water use, since the availability of large amounts of water cannot be guaranteed (see Annex 6). The expected configuration would be either (1) three to four gas turbine generators sets coupled to two steam turbine generators or (2) multiple lean-burn turbo-charged reciprocating gas engines fitted with exhaust heat recovery equipment supplying recovered energy to either a pair of steam turbines or to similar plants to optimize

energy recovery. The plant shall be designed taking into account equipment redundancy and reliability.

The plant and components shall be designed to meet the following:

Annual plant availability (where Availability Factor % = Available Hours/8,760 × 100%	Guarantee by contractor
Minimum plant design life	20 years
Expected normal starts per year	30
Maximum expected starts per year, per unit	100
Plant to be suitable for rapid loading and unloading	
Starting reliability	above 95%

This package will cover the design, selection, supply, and commissioning of the following items, depending on their applicability to the technology to be used by the selected contractor:

- Site preparation
- Foundations
- Buildings to house the generating plant, storage of spares, workshop, and control room
- Plant roads, security fencing, guardhouse, and landscaping
- Supply gas pressure reduction or compression station with custody transfer metering and gas heater
- Selection and supply of gas-fired generator sets (gas turbines or reciprocating lean-burn gas engines)
- Steam turbine generator sets for combined cycle generation, if selected as part of the package
- Combustion inlet air filtration equipment
- Combustion air cooling equipment, if economics show improved overall performance
- Exhaust heat recovery steam generators (HRSGs) for generation of steam
- Exhaust heat recovery units attached to the exhaust stacks of the gas engines to generate hot fluid (140 °C) for use in the gas conditioning plant
- Air cooled cooling equipment for steam condensers and prime mover cooling
- Cooling tower(s), if feasible
- Gas ductwork and exhaust stacks
- Instrumentation, controls, and supervisory, control, and data acquisition (SCADA)
- High-voltage switch rooms, switchgear, metering, switchyard, export transformers, reticulation to nearby high voltage (HV) substation, and connection to HV bus
- Electrical reticulation on site—low voltage—lighting, pumps, fans, etc.

- Water treatment plant with storage for chemicals, treated water, and waste disposal system
- Testing laboratory with necessary equipment and chemicals for plant water testing
- Auxiliary equipment such as lifting and maintenance equipment
- Auxiliary gas-fired start-up boiler for steam turbine option
- Auxiliary diesel engine and generator for black start and emergency operation
- Compressors for plant and instrument air and reticulation system
- Firefighting and alarm system
- Potable and fire water reticulation system
- Liquid waste and sanitary waste disposal system
- Repairs to 110 kV overhead transmission cable to restore the transmission system to service (the 110 kV line repair between Sheberghan and Mazar-e-Sharif is included in this package to allow the transmission of power in the local region before the NETS is completed—see Section 5.2.2. of Annex 5, and Appendix Q)
- Spare parts and consumables for the first year of operation
- Training of operators
- Operation and maintenance services for first life cycle of plant
- Special tools
- Provision of accommodation and housing for the contractor's and subcontractors' staff during construction and commissioning (alternatively, accommodation may be found in Sheberghan at the discretion of the contractor)

4.1.2 GAS CONDITIONING PLANT AND QARAKENT WATER SUPPLY UPGRADE PACKAGE

The work to be performed under this package includes the full works associated with the gas conditioning plant, and the Qarakent water supply upgrade. The work consists of the design, manufacture, inspection, and testing at the manufacturing facilities; packing for export or internal transport; shipment, customs clearance, taxes, duties, delivery to site, unloading, and storage and handling at the site; complete erection and finish painting; testing and commissioning, performance testing, and handling trials; maintenance and supervision of operation during testing and commissioning; and warranty and inspection prior to final acceptance.

The new gas conditioning plant will be located adjacent to the existing Gerquduq Gas Processing Plant complex and the new power plant. Treated gas will be piped to the power plant, and pressurized hot water raised from the power generation unit's waste heat, if this option is selected, will be piped to and from the gas conditioning plant in a closed loop. The combined cycle option will require an auxiliary boiler and hot water may be drawn from this source if the economics are positive.

Conditioning of the raw gas will involve processes to remove the various impurities:

- Oil and condensate removal
- H_2S and some CO_2 removal
- H_2O removal

- Hydrocarbon dew point suppression (if required)
- Particulate removal

The conceptual design has been based on methyldiethanolamine (MDEA) and triethylene glycol (TEG) technologies and it is expected that these technologies will be installed at the plant. However, the contractor shall propose plant technologies best suited for the application and that best meet the requirements of the specification and site conditions. Plant design shall be based on current best practice for continuous operation with minimum operator intervention and minimum maintenance. The plant will be capable of operating continuously for long periods at all loads, and shall be designed to run for extended periods without having to be shut down for overhaul or for repairs. The plant shall be fully automatic with provision for manual operation.

The plant and components shall be designed for the following:

Design life	20 years
Annual planned operating hours	8,592 hours
Annual planned outage hours	168 hours
Annual plant availability (where Availability Factor %= Available Hours / 8760) × 100%)	98%
Annual distributed control system (DCS) availability	99.5%

The gas conditioning plant will be able to operate at various flows of treated gas; however, it must treat the required flow as shown in Table 4.2. The gross power plant output will vary depending on final configurations chosen.

TABLE 4.2 DESIGN REQUIREMENTS FOR GAS CONDITIONING PLANT

CONDITIONS	UNITS	DESIGN
Nominal power output	MWe	100
Power plant gross efficiency	%	43.5
Plant heat rate (based on low heating value, LHV)	kJ/KWh	8273
Fuel consumption	MWt	241.6
Raw gas LHV (estimate only to be confirmed)	MJ/m^3	33.2
Gas to conditioning plant (excluding gas for glycol regeneration and flare pilots / acid gas incineration)	m^3/day	860,000

The works to be provided under this contract shall include but not necessarily be limited to the following items:

- Site preparation
- Foundations
- Buildings for the gas conditioning plant, storage of spares, workshop, and control room
- Plant roads, security fencing, guardhouse, and landscaping
- Raw gas flow and quality metering
- Free water knock-out vessel / slug catcher

- H_2S removal equipment (using amine) including amine contact tower, flash vessels, condensers, heat tower, reboiler, regenerator, water scrubber, recirculation pumps, amine inception, and storage, handling, and dispensing facilities
- High pressure hot water reticulation system for amine regeneration
- Water removal equipment (using glycol) including condensers, glycol contact tower, reboiler and glycol regenerator, glycol injection, and storage, handling and dispensing facilities
- Dew point suppression using Joule Thompson Throttling Valve and Reheater (required if heavy hydrocarbons exist in adequate quantities—to be confirmed before award)
- Tail gas incinerator / flare system, including liquids knock-out
- Wastewater disposal system including oil separator, storage tank, and leach pit
- Two new wells including buildings and control and electrical reticulation at Qarakent water pumping station
- Fresh water supply equipment including new subsurface pumps, new surface transfer pumps, reverse osmosis units, and day storage tanks
- Plant mechanical auxiliary equipment
- Gas conditioning plant instrumentations and controls, including distributed control system (DCS) and power line communications (PLC)
- Electrical works including a 415V distribution system, lighting system, earthing system, fire detection and emergency alarm systems, telecommunications system, DC power distribution system and AC uninterruptible power system
- Spare parts and consumables for the first year of operation
- Training of operators
- Operation and maintenance services through the first vessels major inspection
- Special tools
- Provision of accommodation and housing for the contractor’s and subcontractors’ staff during construction and commissioning (alternatively, accommodation may be found in Sheberghan at the discretion of the contractor)

4.2 EVALUATION OF TENDERS

Detailed evaluation criteria will be developed in conjunction with the MEW. The overall goal is to pick the tenderer who proposes a reliable configuration with the lowest-cost lifetime cost per kWh of electricity. Tenderers must be qualified, and their proposals will have to pass a rigorous technical screening and evaluation.

There are a few basic tenets incorporated into the tender documents, as requirements, for the power plant. These are outlined below.

- *Performance based, specify results desired*—The fundamental approach to the tender is to give tenderers the freedom to propose any technology that best meets the performance specifications. Acceptable technologies include gas turbines or reciprocating engines, with or without a steam cycle (an added steam turbine using waste heat and dry cooling system), as constrained by the lack of water in the project site area.

- *Flexibility incorporated to get creative and economical responses*—AEAI has thoroughly studied various technologies and equipment choices for the Project. However, there may be special circumstances on the part of potential suppliers that give rise to unexpected discounts. Such circumstances may be due to other projects that were cancelled, a strategic decision to penetrate certain markets especially quickly, an imbalance of inventory, a need to demonstrate some certain technology, or some other unforeseeable market pressure. Unexpected discounts could possibly offset the efficiency difference between reciprocating engines and turbines. Also, the lack of water will change what tenderers may propose vis-à-vis a site location without water constraints. Final selection will be made on the basis of the total overall evaluated cost to USAID and the MEW.

  The tender process will not be technologically prescriptive. There will be flexibility to accommodate the widest possible set of reasonable configurations, so as to achieve the best possible economic result.

Figure 4.1 presents a hypothetical example of an evaluation of several tenders. This evaluation is based on a formulaic evaluation of overall economics of a facility's lifetime. In the example shown, the offer with the lowest upfront capital cost is not selected as the best choice because another offer presents better lifetime economics. During the actual project evaluation, the criteria and formulas will be more tightly defined and elaborated to assure a transparent evaluation process.

The numbers shown in Figure 4.1 are for illustrative purpose only, to show how the calculations may be made.

EXAMPLE Total Cost Based on Capital Cost plus Operating Cost, normalized to cents per kwh. **EXAMPLE**

Shaded figures to be provided by bidders

The numbers shown are for illustrative purpose only, to show how the calculations may be done.

Engineering Data	Package 1	Package 2	Package 2	Package 2	etc …
Power Capacity - SITE CONDITIONS (MW)	102.3	108.1	102.0	99.8	
Net heat rate SITE CONDITIONS (kJ/kWh)	7950	7716	7400	9125	
Guaranteed Availability	94.6%	90.6%	95.0%	91.0%	
Gas Price - $/GJ	2.01	2.01	2.01	2.01	

Capital Costs ($000)	Package 1	Package 2	Package 2	Package 2	etc …
TOTAL PROJECT EPC COSTS	110,014	184,825	145,056	97,560	
Financing Rate (debt/equity blend, illustrative numbers only)	10%	10%	10%	10%	
Years (illustrative numbers only)	20	20	20	20	
Annual Financing Charge	12,922	21,710	17,038	11,459	
Capital Cost Component per kWh - ¢/kWh	**1.52**	**2.53**	**2.01**	**1.44**	

Operating Expenses	Package 1	Package 2	Package 2	Package 2	etc …
Annual Gas Expense	13,544	13,309	12,626	14,592	
Bidders Annnual O& M (to be validated)	10,595	8,582	9,560	11,197	
TOTAL ANNUAL OPERATING EXPENSES	24,139	21,891	22,186	25,789	
Energy Production (MWH)	847,595	858,164	848,844	795,566	
Operating Cost per kWh - ¢/kWh	**2.85**	**2.55**	**2.61**	**3.24**	

Total Cost per kWh	Package 1	Package 2	Package 2	Package 2	etc …
Capital Cost per kWh - ¢/kWh	**1.52**	**2.53**	**2.01**	**1.44**	
Operating Cost per kWh - ¢/kWh	**2.85**	**2.55**	**2.61**	**3.24**	
Total cost per kWh - ¢/kWh	**4.37**	**5.08**	**4.62**	**4.68**	
RANKING	**1**	**4**	**2**	**3**	

Figure 4.1 Illustrative Example of a Tender Evaluation

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