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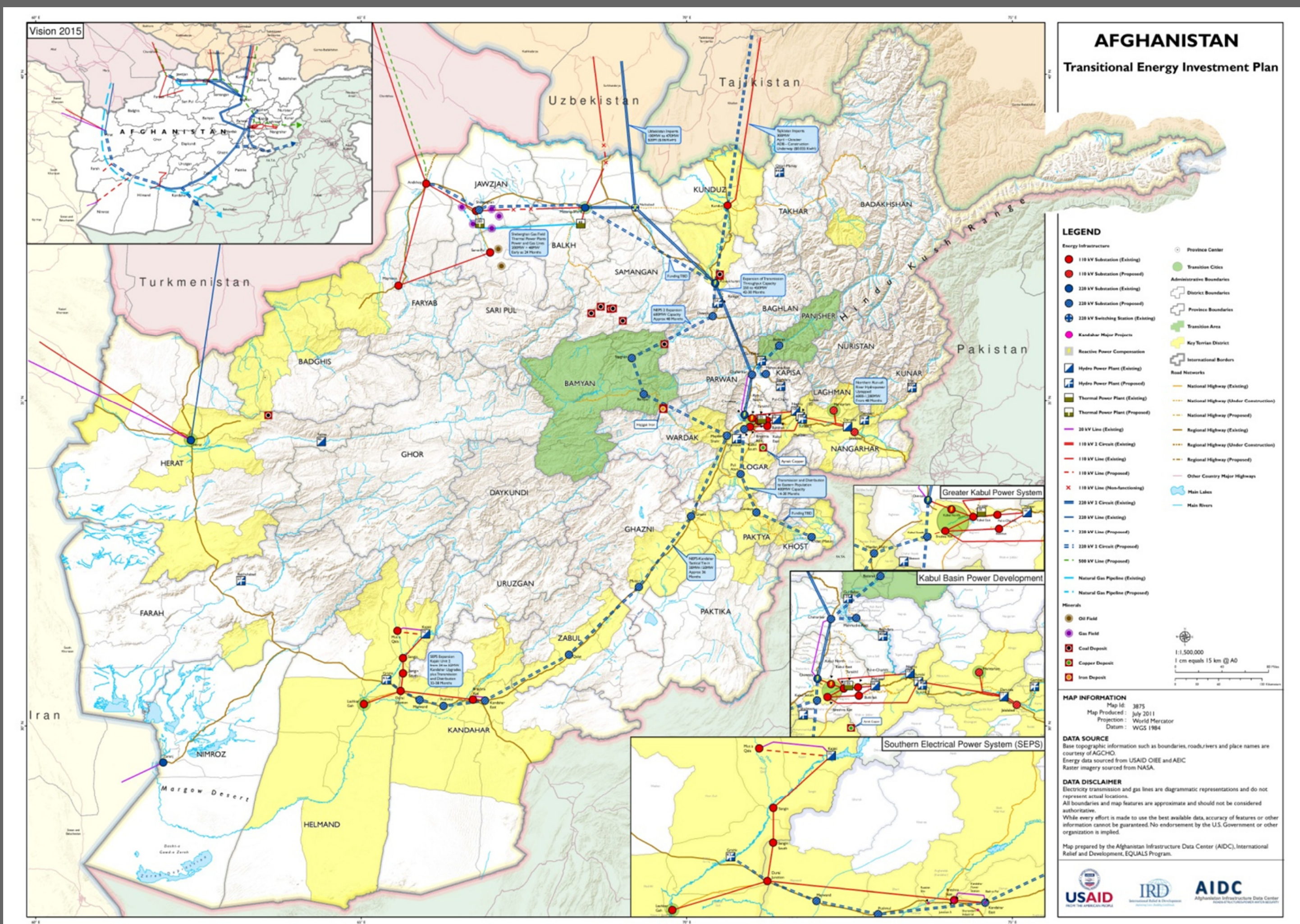
ENGINEERING SUPPORT PROGRAM

WO-LT-0051

Northeast Power System (NEPS) and Southeast Power System (SEPS) Alternatives Study



February 5, 2012

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Principal Contacts:

[redacted]
VP International Operations
Tetra Tech, Inc.
Washington, DC
[redacted]

[redacted]
Senior Vice President
Tetra Tech, Inc.
Framingham, MA
[redacted]

[redacted]
Project Manager
Tetra Tech, Inc.
Framingham, MA
[redacted]

[redacted]

[redacted]
Chief of Party
Tetra Tech, Inc.
Kabul, Afghanistan
[redacted]

TETRA TECH

February 5, 2012

[redacted] COR
[redacted] ACOR
USAID – Office of Infrastructure, Engineering and Energy (OIEE)
Café Compound
U.S. Embassy
Great Masood Road Kabul, Afghanistan

Re: WO-LT-0051 Technical and Cost Overview of Proposed Upgrades and Additions to the Current Afghanistan Northeast Power System (NEPS) and Southeast Power System (SEPS) Final Report

[redacted]

Enclosed is the final report prepared for WO-LT-0051.

I look forward to meeting with you to discuss this report.

Respectfully,

[redacted]

Chief of Party (OIEE-AESP)
Tetra Tech, Inc.

Cc: [redacted] (USAID-OIEE)

AFGHANISTAN ENGINEERING SUPPORT PROGRAM

WO-LT-0051
Northeast Power System (NEPS) and Southeast Power System (SEPS) Alternatives Study

February 5, 2012

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1.0 Acronyms

ADB	Asian Development Bank
AEIC	Afghanistan Energy Information Center
BCM	Billion Cubic Meters
CSP	Concentrated Solar Power
DABS	Da Afghanistan Breshna Sherkat (Afghan power company)
EPC	Engineer-Procure-Construct (contracting method)
HPP	Hydroelectric Power Plant
KESIP	Kabul Electricity Service Improvement Program
km	Kilometer
kV	Kilovolt
kWh	Kilowatt-Hour
MCM	Million Cubic Meters
MoU	Memorandum of Understanding
MVA	Megavolt-Ampere
MW	Megawatt
MWH	Megawatt-Hour
NEPS	Northeast Power System
NFPP	Northern Fertilizer and Power Plant
NLCC	National Load Control Center
NWPS	Northwest Power System
OIEE	Office of Infrastructure, Energy and Engineering
O&M	Operation and Maintenance
OPIC	Overseas Private Investment Corporation
PPA	Power Purchase Agreement
PV	Photovoltaic
ROM	Rough Order Of Magnitude
ROR	Run-of-River

RPC	Reactive Power Compensation
SCADA	Supervisory Control and Data Acquisition
SEPS	Southeast Power System
SGFDP	Sheberghan Gas Field Development Project
SWPS	Southwest Power System
TPP	Thermal Power Plant
USAID	United States Agency for International Development
USD	United States Dollars
VA	Volt-Ampere
VAR	Volt-Ampere Reactive
WTE	Waste-To-Energy

2.0 Definitions

$K	$1,000
$M	$1,000,000
AC (Alternating Current)	Electric current flow that periodically reverses direction
Capacity	The maximum rated output of a generator, prime mover, or other electric power production equipment under manufacturer conditions-usually indicated in units of kilowatts (kW) or megawatts (MW) PV production capacity is in kW or MW DC
Capacity	Operational capacity of generation and transmission facilities (usually less than nameplate capacity because of wear)
Constrained Demand	Desired delivery of power demand where constrained by transmission and distribution limits
DC (Direct Current)	Unidirectional current flow
Demand	The actual power delivered to end use customers (usually less than constrained demand, since customers would use more power if available)
Gas Sweetening	Chemical processing of natural gas feedstock to reduce acid gas constituents
Generation	The large-scale production of electric power for industrial, residential, and rural use, generally in stationary plants
Hectare	The area of a square 100 meters on a side (10,000m^2, 107,639 ft^2, or 2.47 acres)
High Head Hydroelectric Power Plant	Generation facility utilizing a large reservoir to provide hydraulic head and water storage for year-round electrical generation
Import	Transmission of electrical power across international boundaries

Insolation	The amount of solar radiation striking a given area in a given period of time
Inverter	An electrical device that converts direct current (DC) to alternating current (AC)
kWh	Kilowatt-hour, a measure of energy
MW	Megawatt; a unit of power equal to 1,000,000 watts
Nameplate Capacity	All installed units are operated at full design rating
Operations & Maintenance (O&M):	The day-to-day activities required to keep a power plant producing at rated capacity, including operating staff expense, preventive and predictive maintenance and major overhaul
Photovoltaic (PV)	Relating to the production of electric current at the junction of two substances exposed to light.
Reactive Power Compensation	Transmission system components used to enhance stability, reliability and capacity
Run-of-River	Hydroelectric generation facility utilizing a small diversion or no reservoir capacity – may be seasonally operated depending on availability of water reserves
Sarobi 2-1 & Sarobi 2-2	Proposed run-of-river hydroelectric generating facilities on Kabul River. Conceptual design prepared by Soviet Union, 1988.
Sarobi II	Proposed high head hydroelectric power plant on Kabul River. Origin, date, and status of conceptual and feasibility studies unknown.
Scalable	A system, network, or process that is capable of handling a changing amount of work, or that is able to change size to accommodate the new workload.
Sour Gas	H2S concentration exceeds 5.7 mg/m^3. Acids in sour gas can corrode piping and system components.
Sweet Gas	H2S concentration below 5.7 mg/m^3
Synchronization	Manipulation of generating and transmission sources to match phase, voltage, and frequency; allows parallel transmission
Tracker	A mechanical device that repositions solar receptors to maximize radiation received by them
Twinning	Drilling a new exploitation well near an existing exploitation well

3.0 Referenced Reports

Note: Conclusions in this report are based on conclusions of prior investigations and reports, including but not limited to the following referenced reports. Additional study is required to validate the suitability, cost and schedule of any option or combination of options.

"Kabul City Medium-Voltage Distribution System Assessment Report": AEIC, January 2010

"Kandahar Provincial Summary Report": LBG/B&V, May 2010, USAID Contract # 306-I-21-06-00517-00

USAID Afghanistan Engineering Support Program, WO-LT-0030, "Jawzjan Province 200 MW Gas Fired Generating Plant Feasibility Study," Revision # 1 – July 6, 2011

USAID Afghanistan Engineering Support Program, WO-A-0043, "Project Review Report on Proposed Shatoot Dam and Reservoir Project and Sarobi II Hydroelectric Dam Site (Kabul River Basin, Eastern Afghanistan)", September 30, 2010.

Islamic Republic of Afghanistan Ministry of Economy Inter-ministerial Commission for Energy (ICE) "(Draft) Energy Sector Status Report – July-September 2011"

USAID Afghanistan Engineering Support Program, WO-LT-0012, Pul-e-Khumri to Chimtala Transmission Line Study – Addendum #4, September 23, 2011

USAID Afghanistan Engineering Support Program, WO-LT-0023, Afghanistan Electrical Transmission and Generation (T&G) Long-Range Planning Study, October 18, 2011

Project Information Sheet, Sheberghan Gas-to-Power Plant Feasibility Study "Assessing Domestic Gas-To-Power Options – Diversifying Afghanistan's Energy Mix" February 2006.

Sheberghan Gas Field Development Project (SGFDP), "Ranking of Potential Wells for Twinning and Cost Estimates" March 18, 2011

Sheberghan Gas Field Development Project (SGFDP), "Critical Path for Sheberghan Gas Field Development" February 15, 2011

USAID Afghanistan Engineering Support Program, WO-A-0052, NEPS to Kandahar Tactical Tie-In, September 6, 2010

4.0 Executive Summary

The objective of this report is to review proposed NEPS and SEPS upgrades and additions to determine investment priorities that would help to provide a sustainable, functional and stable power system in Afghanistan. The options studied herein are based on direction provided by USAID OIEE and their expressed priorities.

Key findings:

- There is insufficient electrical power available to meet the need of the connected customers. So as not to overload the system, the power to large residential areas in Kabul are turned off (called load shedding) for several hours or for most of an entire day.
- Tajikistan and Uzbekistan will not allow their imported 220kVpower to be synchronized (operate on the same line at the same time) with each other. Also, they will not allow Afghanistan's internally-generated power generation stations to synchronize (operate on the same line at the same time) with their respective power systems. This is due to the fear that the daily service interruptions and voltage swings in Kabul could disturb the Uzbek or Tajik power systems. This increases the cost of operations by denying full use of the inexpensive hydropower generation.
- A mix of alternative solutions such as increasing the 220kV line and substation capacity into Kabul, new gas fired generators (Sheberghan or Kud Bergh), Photo Voltaic at Kandahar, New Hydro Power at Bamyan and Sarobi, and additional import lines (Herat to Kandahar) should be given serious consideration.
- A distribution system survey to list easily identified problems for each distribution area should also be executed. An electrical system cannot be operated efficiently without effective distribution.

The following table lists opportunities to improve the Afghanistan power system.

Options for Action:

Description	Time Frame (mo)†	Execution ROM ($M USD)	Feasibility Study (FS) or Concept Design (CD) ROM‡	Risk (Will success meet the goal)	Comments
Provide an assessment of existing NEPS infrastructure and model possible system additions (such as the NEPS-SEPS connection) through 2016 using the PSS/E model. Also evaluate SEPS possible options such as Photo Voltaic or new line from Herat. (See AESP LT-WO-0053 for more details.)	18 - 30	$TBD based on study and recommendations	CD: [redacted] 4 mos.	Yes	The deliverable for this will be a more detailed report and will assist in evaluating the concept design details for AESP LT-WO-0048 (NEPS-SEPS) and AESP LT-WO-0054 (RPC/automation and additional Transformer)
Install additional RPC at Chimtala to increase the 220kV line capacity to a nominal 450MW and automate some existing RPC. Also install a matching 160MVA transformer to increase the Chimtala substation capacity. (See AESP LT-WO-0054 for more details.)	18 -30	[redacted]	SOW and ROM for Creating a Concept Design (CD) is in process	Yes	This is the number one project that will have the greatest impact on DABS and Kabul with the least risk of failure. The AESP LT-WO-0054 deliverable will be a concept design package.
Install 21 - 30MW solar Photo Voltaic Generation and Transmission at Kandahar.	18 - 30	[redacted]	Feasibility Study is not required	Yes	A SOW and ROM to develop a Concept Design Package would be the next step to take in this process.

Description	Time Frame (mo)†	Execution ROM ($M USD)	Feasibility Study (FS) or Concept Design (CD) ROM‡	Risk (Will success meet the goal)	Comments
Rebuild the damaged/inoperable 110kV line from Uzbekistan to Mazar	TBD	TBD	TBD	Yes	This has not been studied in any detail, however the idea appears sound.
Implement SCADA improvements to allow the synchronization of Hydro and import power. This would allow the less expensive hydro power systems to contribute a greater percentage of the kWh consumed and therefore increase sustainability for DABS.	24	$TBD based on study	[redacted] 6 mo	Yes	Much will be discovered concerning the status of SCADA system through AESP LT-WO-0053 and AESP LT-WO-0054, however more will need to be known. The deliverable would be report suggesting needed improvements.
Construct Sarobi 2-1 & 2-2 Hydro Power Plants. These are Run of the River (RoR) designs so that a dam does not need to be constructed.	58 - 70	[redacted]	[redacted] 12mo	Yes	This project should be high on the medium to long term list as it would create a much needed addition to generation in a location that does not need to travel over long distances.
Install Micro Hydro's, small PV systems, or diesel generators in un-served areas. NOTE: the diesel generators could be provided on nominal lease terms to localities to create a small CO-OP that must show they will be self-sustaining.	24	TBD	TBD	Yes	Areas like Bamyan could be more quickly and cost effectively served by considering a small generation plant.
Construct a 229 MW generating plant at Kud Bergh or Sheberghan. (See study reports completed as part of AESP LT-WO-0024 and AESP WO-LT-0030.)	18 - 30	[redacted]	[redacted] 3mo	Yes	Assumes sweetening plant (not included in this estimate) exists; Transmission lines or gas lines are not included in this estimate. The next step would be to create a Concept Design Package.
Construct Gardez-Ghazni 110kV Single Circuit line	18	[redacted]	TBD	Yes	Assumes that the 220kV line to Gardez is complete. The next step would be to create a Concept Design Package.
Construct NEPS-SEPS 220kV line. (See AESP LT-WO-0048 for more details.)	48 – 60	[redacted]	SOW and ROM for Creating a Concept Design is in process	Maybe	This meets the goal of tying the disparate electrical systems together. Since Kabul is presently as starved for power as Kandahar is, this could cause some additional load shedding at Kabul if additional power is not available to Kabul upon project completion.

† Estimated time frame to place project in service or complete task. Includes, as applicable, preparation of task orders, completion of studies and/or technical specifications, tender preparation, bid preparation by contractors, bid review and award, detailed engineering, procurement and construction.
‡ Estimated time frame is for the actual time to execute the work, beginning with release of a signed task order and ending with completion of the study or specification.

5.0 Scope

The objective of this report is to:

A. Review proposed NEPS and SEPS upgrades and additions; review options available to USAID for strengthening and expanding NEPS and SEPS electrical power generation, transmission and distribution systems in Afghanistan; and provide:
   - Technical evaluations

- ROM cost overview
- Benefits
- Briefing-level discussion

B. Determine the investment priorities that could be pursued by USAID toward providing a sustainable, functional and stable grid-based power system in Afghanistan from these options:
   1. Technical viability of NEPS to SEPS high-voltage transmission line connection
   2. Potential new power sources
      - Sheberghan Thermal Power Plant
      - Sarobi Hydropower Plant
      - Imports
   3. Transmission line needs
      - Uzbekistan to Mazar-e-Sharif
      - Sheberghan spur
      - Naibabad to Kunduz
   4. How to best utilize the new Tajik import line
   5. Reactive Power Compensation (RPC) to increase capacity on existing and proposed transmission lines
   6. Jalalabad to NEPS integration options and implications
   7. SEPS diesel-powered generation replacement options
   8. Impacts of additional NEPS and SEPS electrical distribution systems
   9. Overall grid power quality and stability

C. Evaluate the feasibility and impact of 300-MW import from Turkmenistan; installing a new 220-kV line from Herat to Kandahar.

D. List various options in a table.

6.0 Technical Viability of NEPS-to-SEPS High-Voltage Transmission Line Connection

6.1 Discussion

A. Connection of the NEPS and SEPS electrical systems has been evaluated from a construction cost and feasibility perspective as well as from a basic electrical performance perspective[1]. The project consists of connecting the electrical transmission system in the Kabul area to the electrical transmission system in the Kandahar area with a 220-kV line, which could be single-circuit or double-circuit.

   1. [redacted].
   2. 4-yr design-construct time frame (excluding funding and decision durations).
   3. 569-km line length.
   4. Constructed along the ‘Ring Road’ to reduce construction cost and schedule.

[1] USAID AESP WO-A-0052, NEPS to Kandahar Tactical Tie-In, September 6, 2010
[2] Jacobs NEPS Electrical Transmission, Project # FDWD5006, May 2, 2011

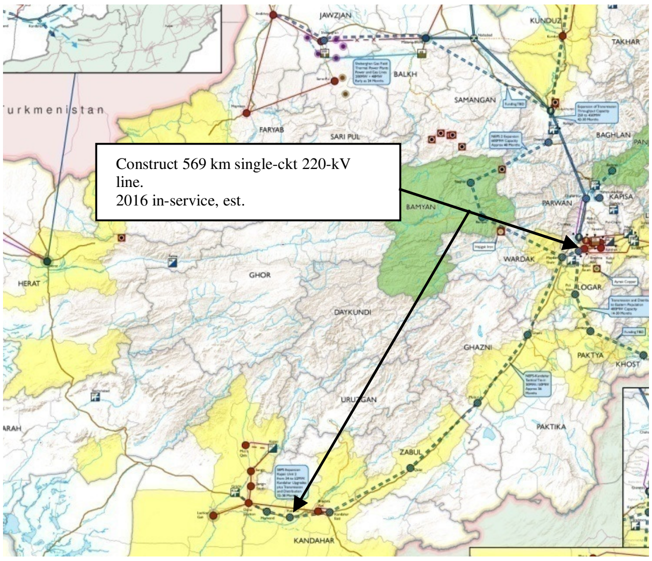

Figure 1: NEPS-SEPS Proposed Tie

B. Advantages
1. Industry-standard, low-tech, familiar solution.
2. Grid-connect opportunity for over 425,000 urban residents[3] in provinces along the Ring Road.

Kandahar	374,000
Ghazni	54,000
Zabol	11,000
Paktika	3,000
Wardak	3,000

3. Minimizes need for $0.53/kWh diesel generation in Kandahar and other Ring Road areas.
4. Improves air quality in Ring Road communities.
5. Improves power quality and power stability in Kandahar and other Ring Road communities.

C. Disadvantages
1. 2016 or later in-service date.
2. Reduces amount of power available to Kabul area by 30-50 MW in the near-term.
3. May require RPC similar to that proposed for the Pul-e-Khumri to Chimtala line (an additional [redacted] or more).
4. Introduces a third un-synchronized source to Kandahar requiring separation from Kajaki and diesel sources.
5. This is a long transmission line and consequently has increased exposure to both insulator flashovers and structural failures. Insulator flashovers are usually caused by lightning and normally do not cause outages of more than a few seconds, if automatic reclosing is employed. Structural failures are the result of a variety of causes, including extreme weather events, soil movement, and intentional damage. Structural failures usually take from a few days to a few weeks to repair, depending upon accessibility, terrain, weather, the number and type of repairs/replacements required, and the advance preparations that are in place.
6. Costs [redacted] per existing Kandahar City DABS customer[4].

[3] Source: Afghanistan CSO Population data 1389
[4] Source: http://www.afghaneic.org/, DABS Customer Database, accessed Nov. 18, 2011 ($465M/45,000 people)

6.2 Considerations

A. Existing load at Kabul exceeds existing transmission capacity. Allocating 30-50 MW of the limited Kabul supply to Kandahar will contribute to even greater Kabul supply-demand imbalance.

B. Lead-time for transmission line construction and commissioning is approximately 48 months.

C. Construction of a transmission line from Kabul to Kandahar could add 10-30 MW of non-Kandahar City loads to the grid including[5]:
- Maydan Shahr
- Sayidabad
- Ghazni
- Qarabagh
- Gelan
- Qalat
- Jaldak
- Kandahar East

D. Connection of NEPS to SEPS will extend delivery of more-reliable, low-cost electricity to customers in southern Afghanistan through the import lines in the North.

E. Connection of NEPS to SEPS may reduce Kandahar's dependence on diesel-power generation.

F. Power imported from Turkmenistan, Uzbekistan, and Tajikistan may be limited in supporting the peak (winter) load in Afghanistan.

G. ROM cost for 590-km single-circuit uncompensated line is about $[redacted].

6.3 Constraints

A. Existing Afghan winter-peak demand exceeds Afghan winter-peak supply by approximately 219 MW.

B. Connection of SEPS to NEPS will increase the disparity between NEPS supply and demand by approximately 30 MW for the wintertime peak.

C. Power quality will be reduced relative to the likely increase in frequency of rolling blackouts in Kabul—and potentially Kandahar—due to more-limited supply. This will also add stressors to the electrical system resulting in additional equipment wear.

D. Each *uncompensated* 220-kV line (590 km length) is voltage-drop-limited to ~130 MW of load, unity power factor, steady-state conditions[7,8]. (Uncompensated means RPC is not installed.)

E. Each *compensated* 220-kV line (590 km length with reactive power compensation) is voltage-drop-limited to ~200 MW of load, unity power factor, steady-state conditions[9]. (Compensated means RPC is installed.)

---

[5] Islamic Republic of Afghanistan Ministry of Economy Inter-ministerial Commission for Energy (ICE) "(Draft) Energy Sector Status Report – July-September 2011", p. 23

[6] Jacobs NEPS Electrical Transmission, Project # FDWD5006, May 2, 2011

[7] Voltage-drop limit basis: 10% voltage drop over entire line length.

[8] Limits calculated with simple spreadsheets. Power-flow analysis may produce different values.

[9] Proper compensation level will require study, but reactive power compensation may increase line loading capability by 50% over the uncompensated capability.

F. If a second circuit is added at a later date, the first circuit must be de-energized for that construction to occur. If, at that time, Kandahar-area loads exceed the local Kandahar/Helmand province generation capability there will be daily blackouts when the first circuit is de-energized for daily 2nd-circuit stringing operations. Blackout magnitude (in MW) will be approximately the difference between the area daily peak load and the area daily generation peak.

G. If USACE awards and builds a 220kV line from Dasht-E-Barchi to Gardez, a 110kV line could be installed from Gardez to Ghazni if the NEPS-SEPS 220kV is not constructed.

6.4 Conclusions and Recommendations (NEPS—SEPS connection)

A. The proposed connection of the NEPS and SEPS systems is technically viable.

B. The proposed line will further exacerbate Kabul's supply shortfall.
  1. Potential Mitigations:
     - Complete the NEPS RPC project
     - Obtain concurrence to parallel Uzbek and Tajik systems at Pul-e-Khumri
     - Obtain 300 MW wintertime firm supply from Uzbekistan
     - Obtain 300 MW wintertime firm supply from Tajikistan

C. The proposed line will increase the number of Kandahar un-synchronized supplies from two to three, adding further operational complexity and risk to the Kandahar power system.
  1. Potential Mitigations:
     - Commission upgraded Kandahar-area generator controls, to stabilize Kandahar-generated power.
     - Integrate Kandahar-area generation analog and digital SCADA points into the National Load Control Center, further stabilizing Kandahar-generated power.
     - Obtain Uzbek and Tajik approval for synchronized operation between their systems and Kandahar-area generation.

D. Reactive power compensation of the 590-km line will be required and studies must be performed to determine the type and sizing of the RPC equipment.

E. Constructing this long-distance transmission line substantially increases the risk of line-related system faults.
  1. Potential Mitigations:
     - Modern digital relays, with fault-locating algorithms, should be installed to minimize time locating any faults that occur on the line.
     - Concurrently develop distributed generation more closely located to load centers like Kandahar.

7.0 Potential New Power Sources

7.1 Sheberghan

A. The potential of natural gas-fired electrical generating technologies for the installation of a nominal 200-MW electric generating plant to be installed in the Jawzjan Province near the Sheberghan gas fields has been evaluated[10].

[10] USAID Afghanistan Engineering Support Program, WO LT-0030, "Jawzjan Province 200 MW Gas Fired Generating Plant Feasibility Study," Revision # 1 – July 6, 2011, p. 6.

1. The current reciprocating engine and simple-cycle gas turbine technologies available worldwide were evaluated and one option for each technology was selected for further evaluation.
2. Conceptual designs for each option to establish the plant operating and maintenance parameters including net electrical power output, fuel consumption, physical plant layout and major maintenance requirements for comparison purposes have been completed.
3. Installation schedules and cost estimates for both options have been prepared.

SUMMARY TABLE 200 MW NOMINAL OUTPUT PLANT[11]		
	Reciprocating Engine Plant	Gas Turbine Plant
Net Output	233 MW	238 MW
Installed Cost	[redacted]	[redacted]
Installation Schedule[12]	25 Months	25 Months
Fixed Operation and Maintenance (O&M) Cost	[redacted]	[redacted]
Variable O&M Cost	[redacted]	[redacted]
Estimated Annual Total O&M Cost @ 80% Capacity Factor (excludes depreciation)	[redacted]	[redacted]

Table 1: Summary Nominal Output

7.1.1 Discussion

A. Development of the Sheberghan gas fields presents an opportunity to develop known reserves of natural resources to provide low-cost domestic generation of base-load electrical power for the Afghan people. Combining the reserves of Bashikurd and Juma provides more than enough estimated gas reserves to supply a power plant at a rate of 1.2 MCM/day for more than 30 years.[13]

B. The gas field development will require design and construction of a new gas processing (sweetening) plant and completion of additional wells to allow for increased capacity. Because the gas from the fields is “sour” (H_2S concentration > 5.7 mg/m^3), using it for fuel without further treatment would result in rapid degradation of piping and generation components in a new power plant. Therefore, development of a new sweetening plant is required. Regarding gas field development:

1. A 0.9 MCM/day gas sweetening plant has been funded by ADB ($23 million) to support operation of the National Fertilizer and Power Plant and some residential use.[14]
2. Additional gas sweetening capacity will be required to support future industrial (generation) use.[15]
3. Infrastructure (wells, piping systems, compressor stations) development / rehabilitation is required to support reliable delivery of gas to sweetening plants and generation facilities.
4. “Twinning” wells have been funded ($31M by USAID) in the Bashikurd and Juma gas fields to support operation of a proposed 200-MW gas-fired thermal power plant.[16]

[11] Ibid.
[12] This schedule does not include necessary administrative steps like contract development and RFP advertisement, and contract award.
[13] Sheberghan Gas Field Development Project (SGFDP), “Ranking of Potential Wells for Twinning and Cost Estimates” March 18, 2011, p. 6
[14] Ibid, p. 10
[15] Sheberghan Gas Field Development Project (SGFDP), “Critical Path for Sheberghan Gas Field Development” February 15, 2011, p. 15-17.
[16] Ibid, p. 14-15

7.1.2 Considerations

A. The gas field development and subsequent power plant construction has the following considerations:
   1. In early 2011, the U.S. Overseas Private Investment Corporation (OPIC) brought a pair of potential investors in the IPP project to Kabul for a series of meetings with stakeholders. OPIC is prepared to finance and insure the transaction, but outstanding issues on the gas side, particularly the gas processing plant, and the cost of energy on the electric power side, need to be resolved before construction can begin on the power plant.[17]
   2. The use of gas generation will provide Afghanistan with a relatively low-cost ($0.03-$0.05/kWh)[18] supply of domestically-generated electricity.
   3. A gas-fired power plant at Sheberghan would provide much-needed generation capacity in Afghanistan, especially during the winter months when hydro resources are low.
   4. The technology options proposed under previous analyses (gas turbine and reciprocating gas engines) are familiar to the workforce in Afghanistan and are sustainable.
   5. Additional wells and facilities (beyond those currently planned) will be required to support operation of a 200-MW gas-fired power plant at nameplate capacity to ensure a 30-year life cycle.
      a. A 200-MW gas-fired power plant will require 1.2 MCM/day or 13.1 BCM over a 30-year operational life.[19]
         - Wells selected for twinning are anticipated to produce only 0.6–1.0 MCM/day.[20]
      b. Juma- and Bashikurd-supplied gas will be sour (H_2S concentration > 5.7 mg/m^3)[21]
         - Gas sweetening will be required.
         - Gas sweetening plant capital cost is estimated at [redacted].[22]
         - Funding source for a dedicated sweetening plant to support operation of the proposed 200-MW gas-fired power plant has not been identified.
   6. Additional water system development will be required to support operation of the proposed power plant and associated gas treatment plant (~$2M).[23]
         - Water system development is currently unfunded.

B. The 220-kV transmission line from Naibabad to Mazar-e-Sharif has been completed.

C. Extension of 220-kV transmission line from Sheberghan to Mazar-e-Sharif has been funded by ADB[24] (commitment of $75M, contingent on power plant construction). This will be required regardless of final power plant location to support gas field infrastructure (compressing stations, sweetening, etc).

D. The timeline for construction depends on commitment to build the power plant, but was most recently estimated to be approximately 25 months from NTP.

E. ROM cost per MW of capacity for the power plant is about [redacted][25]

7.1.3 Constraints

A. The former 110-kV transmission line connecting Sheberghan to Mazar-e-Sharif will need to be reconstructed at 220-kV to allow for connection of the proposed power plant to NEPS.

[17] Ibid, p. 20
[18] Project Information Sheet, Sheberghan Gas-to-Power Plant Feasibility Study "Assessing domestic gas-to-power options– diversifying Afghanistan's energy mix" February 2006. p. 2.
[19] Sheberghan Gas Field Development Project (SGFDP), "Critical Path for Sheberghan Gas Field Development" February 15, 2011. p. 16
[20] Ibid. p.14-15
[21] Ibid. p. 15
[22] Ibid. p. 17
[23] Ibid. p. 17
[24] Ibid, p. 21
[25] Includes plant construction, sweetening plant, transmission line, and wells.

This transmission line will power the sweetening plant, compressor stations and is a good location to connect the power plant.

B. The extracted gas from the Juma and Bashikurd fields will require sweetening to meet gas turbine equipment requirements.

C. Additional gas supplies will be required to support full-scale operation of a 200-MW gas-fired power plant at Sheberghan.

7.2 Sarobi 2

A. The existing Sarobi-1 Hydroelectric Power Plant (HPP) is located on the Kabul River approximately 61 km east of Kabul City. The facility was constructed during the 1950s and commissioned in 1957. The plant provides a significant portion of mid- and peak-power for the Kabul area.

B. Expansion of the Kabul River generating capacity was evaluated and a feasibility report for the "Sarobi-2 Chain of Hydropower Stations on Kabul River, Republic of Afghanistan" was prepared. Due to the USSR's withdrawal from Afghanistan in 1989, the Sarobi 2-1 and Sarobi 2-2 HPPs were never constructed.

7.2.1 Discussion

A. Sarobi-1 has an installed capacity of 2 units each rated 12 MW (14 MVA) for a total of 24 MW. The plant was built in 1957 but had some protection, monitoring, and controls upgrades performed in 2005. The availability of sufficient water appears to be the most limiting factor for operations at Sarobi.

B. In addition to the existing Sarobi-1 units, construction of additional capacity on the Kabul River has been proposed as Sarobi-2 and has taken two forms:

1. In a 1988 study prepared by the Soviet Union, two run-of-river generating facilities (Sarobi 2-1 and Sarobi 2-2) were proposed for construction downstream of the existing Sarobi-1 installation.
   a. Sarobi 2-1 included a low diversion dam.
   b. No diversion was planned for Sarobi 2-2.
   c. Generating capacity of the Sarobi-2 chain of hydropower stations was approximated at 90-110 MW (more recent sources[26] place the potential Sarobi-2 Hydro Power output at 180 MW).
   d. Feasibility studies and site selection were completed.[27]
      - Preliminary geotechnical studies were completed.
      - Several volumes of the Soviet feasibility study are missing or otherwise unavailable for review.
      - Construction material sources have been identified.
2. References to a "Sarobi II" hydroelectric dam have been identified.
   a. "Sarobi II" is proposed as a 200-meter high-head hydroelectric dam (in comparison, the Hoover Dam is 221 meters).
   b. Feasibility-level designs for the 200-m high dam and appurtenances have not been completed.
   c. Water-rights issues involving Pakistan may impact feasibility of the dam or potential power output.
   d. Irrigation water needs may impact feasibility of the dam or potential power output.

[26] Islamic Republic of Afghanistan Ministry of Economy Inter-Ministerial Commission for Energy (ICE) Secretariat "Energy Sector Status Report January-March, 2011", p. 14

[27] Engineering Support Program, WO-A-0043, "Project Review Report on Proposed Shatoot Dam and Reservoir Project and Sarobi II Hydroelectric Dam Site (Kabul River Basin, Eastern Afghanistan)", September 30,2010. p. 10-14

e. The 200-m dam would be considered a high-hazard facility.

7.2.2 Considerations

A. Some geologic details for the selected Sarobi-2 sites have been performed.

B. Confirmation of geotechnical characteristics of proposed sites could be completed in parallel with design efforts related to the Sarobi 2-1 and 2-2 facilities.

C. Insufficient data has been presented to assess feasibility of the Sarobi II 200-m dam project.

D. ROM cost to construct Sarobi 2-1 and 2-2 is between [redacted]

E. ROM cost per MW of capacity for the HPP stations is between [redacted].

F. Time to study, design, permit and construct may be up to 10 years.

7.3 Imports

A. The Uzbekistan utility (Uzbekenergo) and Afghanistan are operating under a Memorandum of Understanding (MoU) that Uzbekenergo will supply Afghanistan with up to 300 MW of power via the 220-kV double-circuit line from Surkhan substation (Uzbek) to Pul-e-Khumri substation.
   1. Advantages
      - $0.075/kWh (7½ cents per kWh) contract price
      - MoU signed for up to 300 MW capacity

B. Tajikistan and Afghanistan are operating under a 20-year Power Purchase Agreement (PPA), for an eventual import of up to 300 MW of seasonal power, beginning in spring of 2012.[29] Current contract limits appear to be 28 MW in August, 2011 and 35 MW in September, 2011.[30]
   1. Advantage
      - $0.035/kWh (3½ cents per kWh) contract price
   2. Disadvantage
      - Seasonal import does not help Afghanistan meet winter demand

C. Uzbekistan and Tajikistan will not allow parallel connection of their 220-kV networks. Power from Uzbekistan and from Tajikistan is planned to be imported via a 450-MW double-circuit import line from Pul-e-Khumri to Chimtala. Each import provider could possibly use one circuit on the line, with a maximum capacity of 225 MW. Therefore, the 300-MW PPA with each country is in excess of the practical capacity of each provider operating independently on the NEPS.

D. Turkmenistan is presently supplying Afghanistan power in two areas at 110-kV, both isolated from NEPS and SEPS. Turkmenistan is the sole existing source for the NWPS (Andkhoy-Maimana-Sheberghan area). Turkmenistan also serves a portion of the SWPS (Herat area). The agreement between the two countries is reevaluated annually to determine the import amount and tariff.[31] Turkmenistan import is proposed to serve up to 16 MVA of future load in the Qala-e-Naw area in the future (Qala-e-Naw presently does not have grid electric service).
   1. Advantage

[28] Sources: OECD countries (Organization for Economic Co-operation and Development) report construction costs of hydro plants less than 300 MW generally fall in the range of $2M-$3M/MW. Hydropower_Essentials.pdf, 2010, International Energy Agency (www.iea.org)
[29] Islamic Republic of Afghanistan Ministry of Economy Inter-ministerial Commission for Energy (ICE) "(Draft) Energy Sector Status Report- July-September 2011", p. 68
[30] Ibid, p. 13
[31] Ibid, p. 68. Since publication of that source, it is understood that a 300-MW PPA has been negotiated between Turkmenistan and Afghanistan.

- Contract price is less expensive than the cost of diesel generation.

2. Disadvantage
   - The very long distance from a strong Turkmenistan power source (Mary) to Afghan loads (450-1000 km) will limit the amount of useful power import.

E. Iran is presently supplying a portion of the Afghan SWPS (Herat area) at 132 kV, isolated from the remainder of the SWPS and from NEPS and SEPS.

7.4 Conclusions and Recommendations (Potential New Power Sources)

A. Proposed Sheberghan 200-MW gas-fired power plant:
   1. This is a great opportunity to establish an economical base-load power plant in the NEPS system.
   2. Combined-cycle technology should be investigated as a viable option to increase efficiency and/or output of the plant.
   3. The most technically sound location for the plant is near the gas fields. This will minimize gas transmission and connect into the already-funded NEPS-to-Sheberghan transmission line used for connection of the gas field infrastructure.
   4. Additional investment in wells and gas-conditioning facilities are necessary to sustain a 200-MW gas-fired plant near the Sheberghan gas fields.
   5. Significant gas-processing infrastructure investment is needed to enable proper, long-lasting, economical and clean operation of the power plant. Construction of the sweetening plant will make the 200-MW gas-fired plant feasible.

   See AESP LT-WO-0030 for details concerning Sheberghan.

B. Sarobi 2 Hydroelectric Power Plant
   1. Siting and preliminary feasibility studies have been completed for the Sarobi 2-1 and 2-2 ROR stations. Validation of the previous feasibility studies by the Soviet Union should be completed and updated to current conditions.
   2. Insufficient data is available to access the feasibility of a 200-m dam and associated 90-180-MW power plant.

C. Imports
   1. Inability to parallel Uzbek, Tajik, Turkmen, and Iranian power with each other or with Afghanistan-generated power is a substantial constraint to grid development, and diminishes the value of any import option presented.
   2. The 300-MW Uzbekistan MoU could be fully utilized upon completion of the NEPS RPC project.
   3. The 300-MW Tajikistan PPA cannot be fully utilized if 300-MW is supplied by Uzbekistan, due to the 450-MW limit of the compensated Pul-e-Khumri to Chimtala double-circuit line[32] and due to limited 220-110 kV transformation at Chimtala substation.
      a. Potential Mitigations:
         - Construct NEPS II (a second 220-kV line from Pul-e-Khumri to Chimtala).
         - Install additional matching 160-MVA ,220-110 kV transformer at Chimtala.
         - Evaluate the 110-kV line capacity between Chimtala and Kabul City
   4. The 300-MW Tajikistan PPA does not help Afghanistan meet winter-peak loads – the agreement stipulates power export to Afghanistan may not occur for five months of the year (winter), due to supply shortages in Tajikistan.
      - Potential Mitigation: Replacement power supply is needed during the winter (presently diesel).
   5. The Turkmenistan imports do not apply to NEPS or SEPS at this time.

[32] At most, 225 MW from Tajikistan and 225 MW from Uzbekistan could be used simultaneously, each using a separate circuit (maximum rating 225-MW) on the double-circuit (total rating: 225+225=450MW) line.

6. The existing configuration of separation of the NEPS import providers adds additional operational risk due to manual switching by operators of the 220-kV breakers and switches.

8.0 Transmission Requirements

8.1 Uzbekistan to Mazar-e-Sharif

8.1.1 Discussion

A. The existing 23-km, 220-kV, double-circuit line supplying the 220-kV bus at Mazar-e-Sharif is of sufficient capacity for projected loads in Balkh province in the foreseeable future.
   1. Recommended additions
      a. Integrate analog and digital SCADA points into the National Load Control Center via SCADA to allow supervisory oversight and override control.

8.2 Sheberghan Spur

8.2.1 Discussion

A. The proposed 162-km, 220-kV, double-circuit Naibabad to Sheberghan line[33] is of sufficient capacity for projected loads in the Jawzjan, Faryab and Sar-i-Pul provinces in the foreseeable future.
   1. Recommended additions:
      a. RPC on the Sheberghan substation 220-kV bus or on the Sheberghan transformer tertiary windings (if they are specified and installed) to control the bus voltage rise under light-load conditions.
         - If the long-term plan is to construct infrastructure to import power into NEPS from Turkmenistan, Sheberghan may not be the optimal location for RPC at that time.
      b. Under/over-voltage relays to control the RPC.
      c. Integrate RPC controls and other analog and digital SCADA points into the National Load Control Center via SCADA to allow supervisory oversight and override control.

8.3 Naibabad to Kunduz

8.3.1 Discussion

A. There is no operational or reliability benefit to this line at this time.

[33] Note: the ICE Energy Sector Status Report_July-September 2011 appears contradictory on this item. Page 14 mentions transmission line from Sheberghan to Mazar-e-Sharif, while pages 30 and 35 mention the line is proposed to be from Sheberghan to Naibabad.

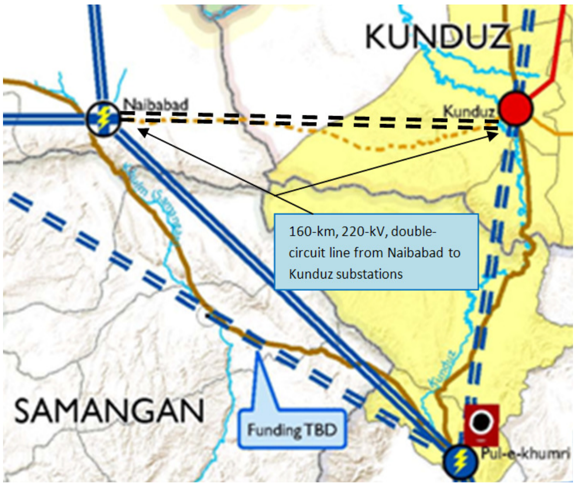

Figure 2: Naibabad–Kunduz area

8.4 Conclusions and Recommendations (Transmission Requirements)

A. Uzbekistan to Mazar-e-Sharif
   1. Integrate analog and digital SCADA points into the National Load Control Center via SCADA to allow supervisory oversight and override control.
   2. Rehab the old 110kV transmission line.

B. Sheberghan Spur
   1. When the transmission line is constructed, install Reactive Power Compensation (RPC) on the Sheberghan 220-kV bus or on the Sheberghan transformer tertiary windings (if they are specified and installed) to control the bus voltage rise under light-load conditions.
   2. Install under/over-voltage relays to control the RPC.
   3. Integrate RPC controls and other analog and digital SCADA points into the National Load Control Center via SCADA to allow supervisory oversight and override control.

C. Naibabad to Kunduz
   1. This proposed but as yet unfunded transmission line would have little or no value other than as a possible means to use Tajikistan imported power instead of Uzbekistan imported power at Naibabad while the sources are unsynchronized.

9.0 Transmission Requirements to Support the Tajikistan Line

9.1 Discussion

A. The 284-km Tajikistan 220-kV double-circuit import line was completed and commissioned in 2011. It is designed to transmit 300-MW from the Tajikistan border to the Pul-e-Khumri substation. To fully utilize this line for the seven months of the year that the Tajikistan PPA allows up to 300-MW import levels, several recommendations should be completed (pending further, more detailed, study).

9.2 Conclusions and Recommendations (Tajikistan Line)

A. Install switched shunt reactors (RPC) at the Kunduz 220-kV bus or on tertiary windings of the Kunduz 220-kV transformers (if they are specified and installed) to control voltage rise of a lightly loaded line

B. Install under/over-voltage relays to control the RPC.

C. Integrate RPC controls and other analog and digital SCADA points into the National Load Control Center via SCADA to allow supervisory oversight and override control.

D. Obtain agreement from both Uzbekistan and Tajikistan that they will allow paralleling of their respective systems at the Pul-e-Khumri substation 220-kV.

E. Obtain agreement from both Uzbekistan and Tajikistan on which SCADA analog and digital points can and should be integrated into Uzbek, Tajik and Afghan National Load Control Centers via SCADA.

10.0 Reactive Power Compensation (RPC) Addition to Increase Capacity

10.1 Discussion

A. Reactive Power Compensation (RPC) is generally required on long high-voltage transmission lines to manage the voltage along the line and at the terminals of the line. RPC is most typically implemented (and presently applied in the NEPS) with switched shunt capacitors and reactors. Switched shunt capacitors and reactors are relatively simple and reliable devices that have been used for many decades throughout the world.

B. As power flow through transmission lines is increased, more sophisticated RPC equipment is needed. In terms of technical sophistication, the next level of equipment includes Static VAR Compensators (SVCs) and series capacitors. These devices were found to be necessary to import higher levels of power from Uzbekistan and potentially Tajikistan in studies performed under WO-LT-0012[34] and WO-LT-0023[35].

C. Series capacitors and SVCs have been successfully used on North American and European power systems for over 40 years and are well-established technology. However, because of their technical sophistication, a higher level of technical capability is required for the people who operate and maintain them. Local engineers should receive adequate training in RPC operation, maintenance, and diagnostics in order to ensure optimal RPC performance and benefit. Serious consideration should be given to the need for competent and fully trained technical staff to operate and maintain these devices when planning for installation.

D. Long-term support contracts with the manufacturers of the apparatus should also receive consideration. This is important because failure of RPC equipment may result in RPC downtime that could be measured in months. The line capacity would be de-rated while the RPC is out of service, which may result in un-served load or the need for expensive diesel replacement power for that duration.

E. The RPC system controls must be integrated into the National Load Control Center (NLCC) to ensure the reactive power requirements are coordinated from a central location. The present RPC installed at Chimtala substation consists of switched shunt capacitors, and is controlled manually. This sometimes causes voltage swings outside acceptable limits, causing relays to trip before operators can intervene. This control method is not sustainable for the NEPS or SEPS networks.

[34] USAID AESP WO-LT-0012, Pul-e-Khumri to Chimtala Transmission Line Study – Addendum #4, September 23, 2011
[35] USAID AESP WO-LT-0023, Afghanistan Electrical Transmission and Generation (T&G) Long-Range Planning Study, October 18, 2011

F. NEPS is the only Afghan system now employing RPC[36], but the general benefits, limitations and control means discussed above will also apply to any future RPC systems installed in Afghanistan.

10.1.1 Considerations

A. Regarding the addition of Reactive Power Compensation (RPC) on existing and proposed transmission lines to increase overall capacity: General statements about the amount of RPC needed to increase power transfer capacity of a transmission line cannot be made with accuracy. Detailed study of the line characteristics, operating parameters and environmental conditions under which it operates must be performed to determine the amount of RPC needed to increase line transfer capability to a specified value. In the case of the Pul-e-Khumri to Chimtala line, the capacity was calculated as approximately 245 MW under the line conditions originally studied. Adding RPC consisting of series capacitors, an SVC and additional shunt capacitors will permit increasing the line capacity to approximately 450 MW for the system scenario investigated. In that instance, the application of RPC doubled the calculated line capacity but increases of that magnitude cannot be guaranteed for every line to which RPC is applied. The engineering estimated cost of construction for that addition is $28M.

B. The RPC required for the NEPS system, which was studied preliminarily under WO-LT-0012 and WO-LT-0023, will need to be defined in detail taking into account the best current knowledge of the electric power system as it exists now and is expected to exist in the future, including specific RPC impacts on power flow and system stability. This definition can be accomplished during the development of tender documents for RPC installation.

10.2 Conclusions and Recommendations (RPC)

A. RPC is necessary to achieve increased import capability from Uzbekistan and Tajikistan.

B. The RPC specification bid package preparation should begin right away.

C. Integrate RPC system controls and other analog and digital SCADA points into the National Load Control Center via SCADA to allow supervisory oversight and override control.

D. Study each transmission line and each system (NEPS, SEPS) as a whole to determine applicability of RPC to achieve optimal power transfer ratings.

11.0 Jalalabad-NEPS Integration

11.1 Discussion

A. Jalalabad is presently an isolated power system, 80 km from the easternmost portion of the existing NEPS system (Sarobi) and is served entirely (except for any self-generation that may exist) by the existing Darunta dam hydropower facility, which has a 7-MW operating capacity. Darunta is being rehabilitated by USAID to increase the plant output to 11.5 MW. Jalalabad’s population of 400,000 is expected to grow to 1.5 million by 2030. In addition the new 208-hectare Hisar-e-Shahi light industrial park, now 90% complete and planned to be served by a diesel generator in the interim, may require about 25 MW of power. The park is projected to generate 6,000 jobs.

[36] This statement is made on the basis that the NEPS and SEPS one-line diagrams available from the AEIC website are accurate as of November, 2011

B. The Darunta dam and reservoir was initially constructed for a capacity of 40-45 MW[37], but silting and damage will prevent that level of refurbishment in the near-term.

C. The Naghlu to Jalalabad 110-kV single-circuit transmission line should be completed in March of 2012. However given that the existing distribution is a 6kV system the new line and substation will be of little value without further investment in the distribution system.

11.2 Options to NEPS integration

A. 25-MW diesel generation; $40M engineering estimated cost of construction, 30-50 cents per kWh O&M cost, including fuel.

B. Dredge Darunta reservoir; install additional generator bays to achieve 40 MW of output. (This requires study to see if it is possible. Moreover, river flow study is necessary to see if minimum flow will sustain a 40-MW generation output.)

C. Local solar combined with wind 30 km north and 30 km east of Jalalabad. See Figure 3, below. [redacted]ROM cost. Integrated solar, wind and hydro sources at Jalalabad could provide a showcase of potential Afghan diversified renewable generation systems. The rehabilitated 11.5-MW hydro plant would provide base-load power while the solar and wind plants provide complementary supply that could allow Darunta reservoir re-filling under certain conditions.

D. Consideration should be given to a ramped-supply approach to providing power to the industrial park, to minimize initial investment in this new venture. Initial power requirements are likely to be low in the initial tenancy, increasing as the park tenancy increases over time. If existing Darunta capacity allows, the initial park electrical service may consist of distribution transformers and secondary/service to the park buildings, with design taking into account later self-generation and/or a dedicated substation for the park. As demand exceeds the ability for Darunta to supply then generator power can be staged to provide the necessary capacity and energy as park growth occurs.

11.3 Implications of Jalalabad–NEPS Integration

A. Advantages
- Significantly increased reliability of the Jalalabad system.
- Increased voltage control of the Jalalabad system.

B. Disadvantages
- Further exacerbates Kabul-area generation shortfall by approximately 25 MW in the near-term.
- Introduces reduced reliability in the Sarobi area due to 80-km additional exposure to transmission line faults or structural failure.

[37] Source: Wikipedia ‘Darunta Dam’, accessed Nov 16, 2011

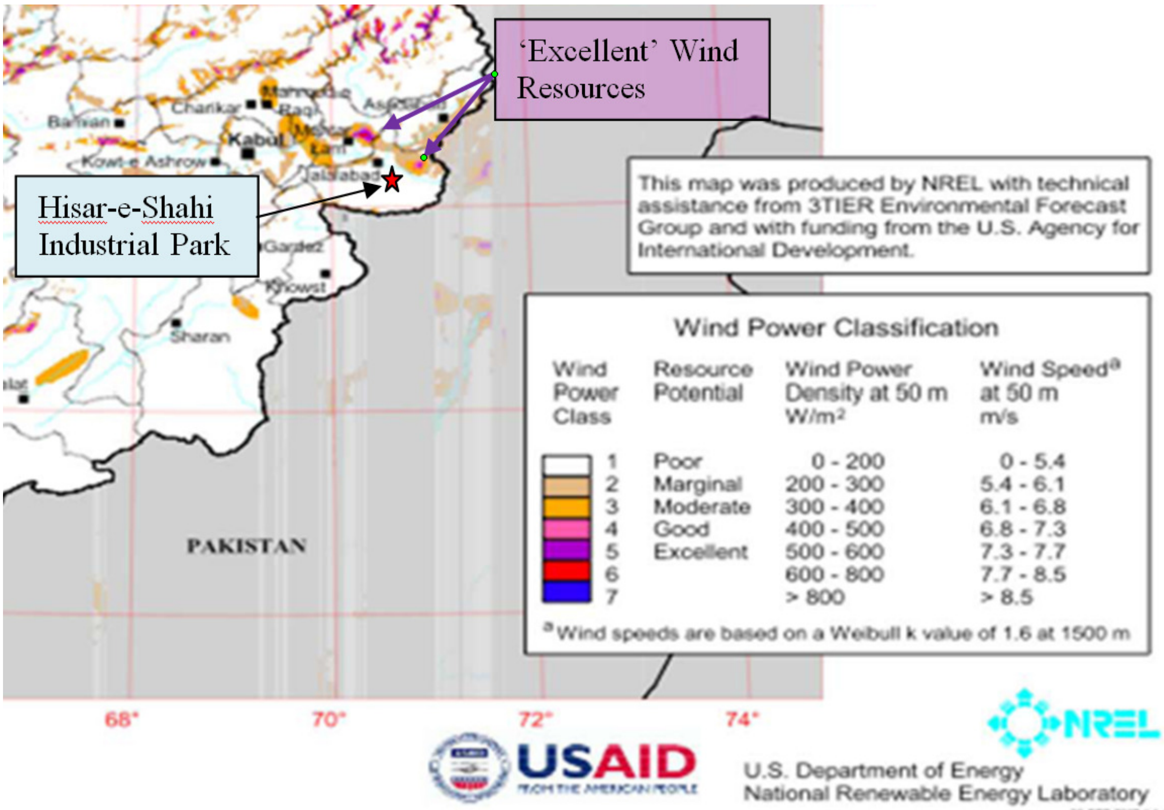

Figure 3: Jalalabad Wind Resources[38]

12.0 Options to Replace Diesel Generation

A. Diesel generation in the SEPS system provides over 18 MW of capacity, at a cost of over $70M/year ($0.53/kWh)[39]. This power is extremely expensive, and likely not sustainable in the long term at this high cost. The following list presents alternatives to diesel power generation, with a brief discussion on each alternative, focusing on the SEPS area:

1. Wind energy: As Figure 4 (below) shows, the areas suitable for wind power generation are clustered at the western border, with a few areas in the mountains of the northeast. With the exception of the area east of Mehtarlam and north of Jalalabad, none of the windy areas are near existing transmission lines. Therefore, any wind development in support of SEPS would require substantial investment in transmission infrastructure. Moreover, wind power is intermittent, and requires energy storage or supplemental power generation to provide a reliable, dispatchable power supply available on a continuous basis.

[38] From: National Renewable Energy Laboratory (NREL)'s "International Wind Resource Maps", available at: http://www.nrel.gov/wind/international_wind_resources.html#afghanistan

[39] E-mail from Roseann Casey (USAID) to George Smith (Tetra Tech) containing spreadsheet "Kandahar diesel generation summary (rev. Oct 23 2011 tmo).xlsx" dated 10/31/2011, 8:34pm.

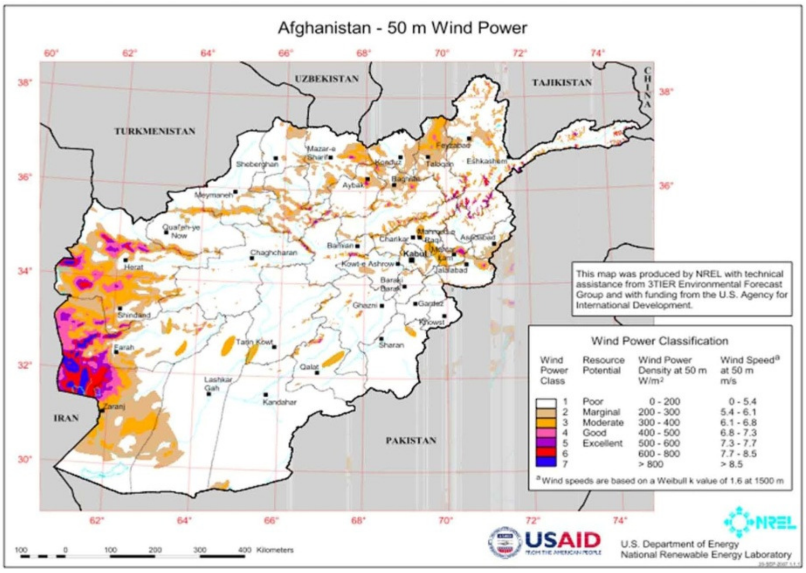

Figure 4: Wind Potential[40]

2. Solar energy (Photovoltaic & Concentrated)
   a. Section 16.0 (on page 29) contains a detailed description of solar alternatives. A brief synopsis follows.
   b. In contrast to wind energy resource, there is abundant solar resource opportunity in Afghanistan, especially in the SEPS area (see Figure 5). Solar generation is scalable in generation capacity and can be put in place more quickly than other generation methods such as hydroelectric or geothermal. Solar energy, like wind energy, is intermittent, and requires energy storage or supplemental power generation (e.g. diesel generation) to provide a reliable year-round, 24-hour power generation source.
   c. Megawatt-scale photovoltaic (PV) solar power projects also require 1 hectare of land area per 250 KW (100 KW/acre) of generation capacity. This large land requirement makes large-scale PV generation challenging, but small distributed solar PV systems (e.g. roof-mounted arrays) are also a reasonable option. Smaller systems may be more secure and offer better opportunities for off-grid operation and use of battery backup systems.
   d. Concentrated solar power (CSP), using thermal energy to generate electricity requires less land area and has a lower initial capital cost as compared to PV systems. However, to provide reliable power, a supplemental power generator is required. These systems are designed on a megawatt scale and require ongoing operations and maintenance similar to a thermal power plant. Some CSP designs incorporate thermal storage, allowing round-the-clock generation.

[40] From: National Renewable Energy Laboratory (NREL)'s "International Wind Resource Maps", available at: http://www.nrel.gov/wind/international_wind_resources.html#afghanistan

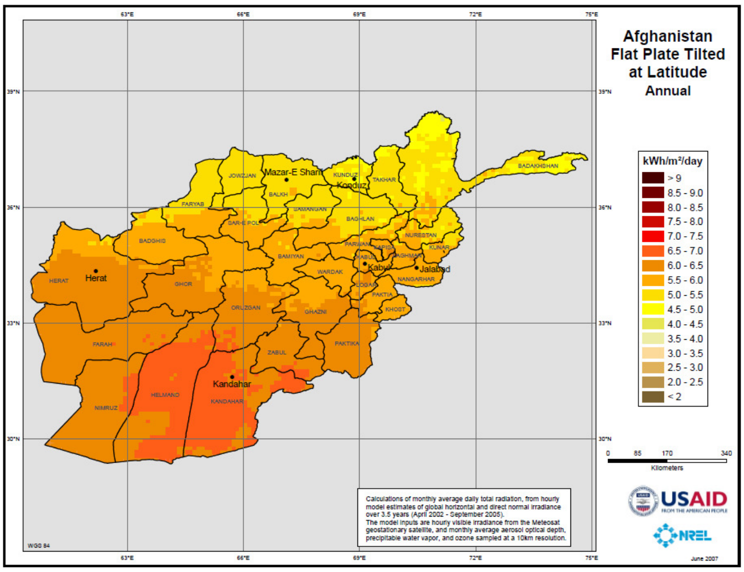

Figure 5: Solar Potential[41]

3. Hydro-electric: Increasing the hydro-electric capacity in the SEPS area is planned, but the timeline is long. A project for adding 17 MW of capacity by installing a third turbine (Unit 2) at the Kajaki Hydro Power Plant has been awarded and was scheduled to complete in 2013, but is currently on hold[42]. Moreover, a static, preliminary model of the 177-km transmission line from Kajaki to Kandahar indicates that the voltage drop limit (95% generated voltage at Kandahar) is reached with a 25-MW output (assuming all power is transmitted Kajaki-Kandahar, and none to Lashkar Gah). This analysis further indicated that sending full rated capacity (51 MW) from Kajaki to Kandahar would likely result in a voltage drop to approximately 85%. Therefore, it is likely that additional transmission infrastructure will be required to effectively use any added generation capacity. A second 177-km transmission line has a ROM of about $100 M.
4. Waste-to-energy (incineration): Waste-to-energy (WTE) for electric power generation shows promise in the SEPS area. One WTE incineration unit commercially available takes a 30 ton/day trash input and yields a 350-KW generation capacity. Kandahar's 500,000 people generate an estimated 355 tons/day of trash, which if fully collected could fuel 3.5 MW of WTE generation. This is proven technology, incorporating commercially available incinerator technology used by the U.S. Army in Iraq to success since 2003. The concern is more with creating and sustaining a garbage collection system.
5. Geo-thermal: Geo-thermal power potential in Afghanistan has not been thoroughly investigated. Cursory studies based on ground temperature indicate there may be limited potential, but much more study is required. Test drilling would be recommended before committing to this technology. Depending on the plant location, substantial transmission infrastructure may be required.

[41] From NREL's solar resource map archive at: http://www.nrel.gov/gis/pdfs/swera/afg_pak/afg_10km_tilt.pdf; map is dated June of 2007.
[42] Islamic Republic of Afghanistan Ministry of Economy Inter-ministerial Commission for Energy (ICE) "(Draft) Energy Sector Status Report- July-September 2011", p. 56.

DIESEL GENERATION ALTERNATIVES						
OPTION	COST TO INSTALL[43] ($/KW)	FUEL & O&M COST /KW-H[44]	ANNUAL COST (18 MW OF GENERATION)[45]	PROJECT TIMELINE†	FEASIBILITY	COMMENTS
Diesel (for comparison)	[redacted]			2-3 yr	High	Easy to install, but substantial ongoing costs.
Wind energy				4-5 yr	Low	Remote sources; requires transmission lines and storage.
Solar photo-voltaic				3 yr	High	Intermittent, requires large area (250KW/hectare).
Concentrated solar power				5-6 yr	Med	May require transmission lines. Storage can be designed in.
Hydro-electric[46]				4-5 yr	High	Long timeline, technical challenges.
Waste-to-energy (incineration)				2-2.5 yr	Medium	Only enough waste to support 3.5MW of capacity.
Geothermal				>5yrs	Low	Requires detailed feasibility study.

† Estimated time frame to place project in service or complete task. Includes, as applicable, preparation of task orders, completion of studies and/or technical specifications, tender preparation, bid preparation by contractors, bid review and award, detailed engineering, procurement and construction.

Table 2: Diesel Generation Alternatives

12.1 Discussion

A. On a pilot scale, solar PV and waste-to-energy could be implemented on a relatively rapid timeline. Scalable distributed renewable generation offers significant promise in the SEPS area, since it does not require expensive transmission infrastructure and ongoing fuel expense. In the SEPS area, importing power directly is unfeasible due to lack of transmission infrastructure connecting the SEPS system with potential power exporters such as Iran or Turkmenistan.

13.0 Impacts of Additional Distribution on System

A. Generation, transmission and distribution systems are all required to successfully bring power to consumers. The portion of the system with the least capacity will be the bottleneck that will constrain delivery of power to consumers. Efficient power system development requires that all three systems be developed in a coordinated fashion.

B. Afghanistan's distribution system is generally in poor condition and much of it is at or near the end of useful life. An Energy Sector Overview article published by USAID[47] states:

[43] Derived from US Energy Information Administration's "Updated Capital Cost Estimates for Electricity Generation Plants", November 2010, available at: http://www.eia.gov/oiaf/beck_plantcosts/pdf/updatedplantcosts.pdf
[44] Ibid.
[45] Assumes O&M for 18MW/yr of generation, or 158,000 MW-h. Since WTE generation is fuel-limited at 3.5MW, O&M for that generation capacity will be $4.5M-$6M.
[46] These costs are to specifically install and maintain 17MW of capacity at Kajaki, per Islamic Republic of Afghanistan Ministry of Economy Inter-ministerial Commission for Energy (ICE) "(Draft) Energy Sector Status Report- July-September 2011". Transmission line installation is not included.

"Distribution is the least[-]developed part of the Afghanistan power system. Its existing condition significantly limits the availability of power supply. It is well recognized that as power supply continues to increase local and regional distribution networks without timely and significant improvement, will emerge as serious constraint in effective power delivery to the end-users."

C. Targeted refurbishment of controls in the existing generation and distribution system would increase system reliability. Moreover, expected increases in generation and transmission will require added distribution to allow increased operational supply to serve constrained demand.

D. With regard to adding distribution:
   1. In most areas (rural and semi-rural), Afghanistan has more load than existing generation can supply. Accordingly, adding distribution without additional generation does not support the goal of a sustainable, functional, and stable grid. With limited capacity (generation and imports), expanding distribution systems merely results in all customers having poor electricity service.
   2. In some areas, demand exceeds not only the available supply, but also the capacity of the distribution system. In these areas, investment in distribution is a necessary companion to investment in generation capacity. Simply put, there's no reason to spend money on generation if you can't distribute the power.
   3. At certain times, in a few areas (e.g. Kabul and Kandahar), there is sufficient supply, but the distribution system is the bottleneck preventing customers from receiving power. This occurs in the summer, when import power and hydroelectric power availability increases. In those areas, adding distribution would reap an immediate benefit. Overloaded distribution feeder lines and transformers are evidence of a distribution bottleneck, and indicate a requirement for additional distribution infrastructure investment.

13.1 NEPS

A. Capacity addition: Kabul has several overloaded transformers; 3 in Kabul City East and 1 in Breshna Kot[48]. This indicates a need for additional distribution capacity. Moreover, additional distribution should be programmed to match any additional generation brought to an area.

B. Targeted refurbishment: In general, the NEPS system is constrained by generation and transmission, so adding distribution would exacerbate this problem. Targeted refurbishment of controls (e.g. install LTC transformers, regulators, distribution capacitors) in the existing generation and distribution system, without adding additional loads, would increase system reliability.

13.2 SEPS

A. Capacity addition: Kandahar experienced overloading on 6 of 7 feeders in the winter of 2009-2010[49]. This indicates a need for additional distribution capacity. Moreover, additional distribution should be coordinated to match any additional generation brought to an area.

B. Targeted refurbishment: As in NEPS, targeted refurbishment of controls in the existing generation and distribution system, without adding additional loads, would increase system reliability.

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[47] Source: http://www.sari-energy.org/PageFiles/Countries/Afghanistan_Energy_detail.asp#distribution, accessed October 14, 2011
[48] From: "Kabul City Medium-Voltage Distribution System Assessment Report": AEIC, January 2010, available at: http://www.afghaneic.org/library/other/Kabul%20Distribution/Kabul%20City%20Distribuiton%20Sytem%20-%20January%202010.pdf
[49] From: "Kandahar Provincial Summary Report": LBG/B&V, May 2010, USAID Contract # 306-I-21-06-00517-00

14.0 Overall Grid Power Quality and Stability

A. Overall grid power quality and stability is poor, and does not meet accepted standards for delivery to domestic and industrial customers. Poor power quality is felt at the customer level through unintentional outages, intentional outages (“rolling blackouts”), voltage sags and swells, frequency excursions and voltage transients.

B. Power quality in Afghanistan, though poor, is still sufficient to power:
- Incandescent lights
- Phone chargers
- Televisions
- Laptop computers
- Electric home appliances
- Home air conditioning units
- Non-precision factory machinery (e.g. presses, stamps)

C. Power quality is <u>not</u> sufficient to power:
- Plasma televisions
- State-of-the-art home electronics
- Modern medical equipment
- High-tolerance manufacturing equipment
- IT equipment like server farms[50]

D. Systems exhibiting poor power quality may adversely affect interconnected systems, exacerbating the difficulty of negotiating power purchase agreements.

E. In a developing nation, however, it is reasonable to accept poor power quality as a tradeoff for a greater number of connections. Even poor quality power will greatly increase residential and business quality of life. Moreover, end-users who require high-quality power (like hospitals) can install power conditioning equipment at their own location.

F. A holistic planning approach should be chosen when evaluating potential infrastructure investment opportunities. Power quality and stability is affected by many factors, including transmission distance, number of generators and types of loads. Using a “systems approach”, and dynamic (as well as steady-state) analysis to study the proposed power grid will likely provide the best and clearest options.

14.1 Recommendations (Power Quality and Stability)

A. The focus on grid-connected supply should not deter funding and progress on off-grid supply opportunities in Afghanistan, particularly in the rural areas that could benefit greatly from day-time or intermittent power from small-scale renewables.

B. There are a number of recommendations for improving Afghanistan’s overall grid power quality and stability:
1. Synchronize all Afghan grid-connected generation with import sources.
2. Perform stability studies on the existing and proposed Afghan transmission and generation systems to identify improvements necessary to minimize loss of generation or imports due to system disturbances.

[50] IT equipment such as server farms typically require ‘pure’ power to the extent that supplies often must be redundant, have failover designs and meet or exceed international power quality standards.

3. Analyze system fault data to determine likely cause of faults as a first step to reducing their frequency or duration.
4. Enable a more-thorough system data historian [load data for all substations, transmission lines, grid-connected generators, substation transformers; distribution feeders; monthly peak demands (MW and MVAR)].
5. Enable an outage historian to track system outages, location, duration, estimated customer count affected, primary cause, secondary cause.
6. Implement under-voltage and under-frequency load-shedding plans to automatically and quickly respond to imminent system collapse.
7. Implement over-voltage protection schemes to automatically and quickly adjust generation and shunt reactors to keep voltage within acceptable limits.
8. Review, update and upgrade transmission, generation, and distribution-system fault protection schemes (relay coordination) to help prevent cascading fault-caused outages.
9. Adopt and specify power quality standards that are appropriate to Afghanistan's emerging transmission grid and distribution system.
10. Integrate distribution substation analog and digital SCADA points into the National Load Control Center via SCADA to allow supervisory oversight and override control.
11. Evaluate the addition of transformer automatic load tap changers, regulators and switched shunt devices to enable practical use of a wider range of supply voltages and to enable monitoring and control of such from the National Load Control Center.
12. Implement condition-based maintenance practices for power system apparatus.
13. Increase the number of analog and digital SCADA points accessed from the National Load Control Center.
14. Power system grids should have generation/import 'unused' capacity (both active power and reactive power) in reserve to control frequency as in-service generation trips off-line. The reserve amount (called spinning reserve) is generally 10% of the required power.
15. Study the distribution system to identify opportunities for VAR control. VAR control will include the addition of static capacitors, reactors and static VAR compensators to minimize the amount of VARs supplied by the power generation resources, maximize stability and improve voltage profiles.

15.0 Impact of Turkmenistan 300-MW Import from Herat-Kandahar

A. Discussion

1. Import and transmission of 300 MW from Turkmenistan to Kandahar, via Herat, is contemplated. The following information is presented to clarify assumptions and highlight concerns. Further, more detailed, analytical study is recommended to refine these areas.

B. Assumptions

1. Power will be generated in Mary, Turkmenistan. (Approximately 1,000 km from Kandahar, distance measured along existing highways.)
2. The power will be natural gas-fueled, and fully available during winter.
3. Turkmenistan will not allow paralleling with any other power supplies (e.g. Iran, Afghanistan hydro, Afghanistan diesel, Uzbekistan).
4. There are existing 220-kV lines from Mary to Herat, currently operated at 110 kV.

C. Considerations

1. 80 MW is currently being delivered from Turkmenistan to Herat at 110 kV. Delivering 300 MW to Herat and on to Kandahar would require 220 kV transmission lines. Neither Herat nor Kandahar has the required infrastructure to accept 220 kV supply; they are configured to accept 110 kV electricity. Refurbishment of the existing 110 kV-20 kV Herat substation to allow it to accept 220-kV power would have an engineering estimated

cost of construction of about $12M and may require extensive outages. Constructing a new 220 kV-110 kV substation would have an engineering estimated cost of construction of about $19M. Similarly, in Kandahar, 110-20 kV substation refurbishment would have an engineering estimated cost of construction of about $12M. To utilize 220-kV supply and construction of a new 220 kV-10 kV substation would have an engineering estimated cost of construction of about [redacted]

2. Herat currently imports some power from Iran. Since Turkmenistan will not allow their power to be synchronized with other sources (per assumptions above), Iranian power and Turkmen power would have to travel to Kandahar on separate circuits of a double-circuit line. Moreover, an inability to parallel Turkmen power with domestic or other imported power sources introduces operational risk by presenting complicated switching issues.
3. Kandahar's distribution system will not utilize 300 MW of supply. Although importing power would replace existing distributed diesel generation, and can supply existing demand, constrained demand cannot be accommodated with the current distribution system. To effectively use this new supply, the distribution system must be upgraded.
4. Kandahar is currently supplied by distributed diesel generation and by hydro power plants at Kajaki. These sources cannot be synchronized with imported power. Since there is no reasonable way to handle three unsynchronized power supplies in Kandahar, one source would be disconnected and used as standby capacity. Furthermore, since hydro output is seasonal (and reduced in the winter), Kajaki may not be able to supply sufficient power in the winter to augment imported power. In this case, costly distributed diesel would still be necessary.
5. Construction and maintenance of a power line from Herat to Kandahar presents significant security challenges.

15.1 Conclusions and Recommendations (300-MW Turkmenistan Import)

A. The proposed import of 300-MW of power to Kandahar from Turkmenistan is technically feasible, based on very preliminary results. More sophisticated modeling is required to ensure dynamic criteria are met and the RPC system is properly sized.

B. Disadvantages:
   1. Expanding the transmission line beyond Kandahar or increasing import power from Uzbekistan or Tajikistan beyond three hundred (300) MW is not advisable and likely not technically feasible.
   2. Adds complexity and risk to the Kandahar power system, by increasing the number of Kandahar un-synchronized supplies from two to three.
   3. Significant substation investment in Herat needed to enable continued use of Turkmen supply.

C. Advantages:
   1. Reduces Kandahar dependence on very expensive diesel generation.
   2. Allows serving distribution load that could not otherwise be served from Kajaki or Kandahar diesel sources alone.

D. Cost & Time Frame

Cost and Time Frame				
Action	**Time Frame† (mo)**	**Execution Engineering Estimated Cost (EEC)**	**Pre-execution study ROM**	**Comments**
Study Herat distribution system	8	[redacted]	N/A	
Study Kandahar distribution system	8		N/A	
Construct/refurbish Herat substation to accept 220 kV power	36		$200K	Only needed if Herat to Kandahar 220-kV line is constructed
Upgrade Herat distribution to accept import power	TBD based on study results		$100K	Scope of work needed unknown until study is complete
Construct/refurbish Kandahar substation to accept 220 kV power	36		$200K	Only needed if Herat to Kandahar 220-kV line is constructed
Upgrade Kandahar distribution to accept import power	TBD based on study results		$100K	Scope of work needed unknown until study is complete
Construct 560-km 220 kV line from Herat to Kandahar	64		$150K	May need study and construction of RPC ($28M minimum).
Upgrade existing 104-km single-circuit Herat to Turkmen border line to double-circuit 220-kV line	32		$100K	Only needed if Herat to Kandahar 220-kV line is constructed
Upgrade existing 410-km Mary to Afghan border double-circuit 220-kV line to 220-kV operation, including necessary upgrades at Mary substation	TBD based on study results		$200K	The scope of work needed to operate the 410-km line at 220-kV is unknown. Only needed if Herat to Kandahar 220-kV line is constructed

† Estimated time frame to place project in service or complete task. Includes, as applicable, preparation of task orders, completion of studies and/or technical specifications, tender preparation, bid preparation by contractors, bid review and award, detailed engineering, procurement and construction.

Table 3: Costs and Time Frames for Turkmenistan Import

16.0 Solar Power

16.1 Executive Summary

- The Kandahar region receives a significant amount of sun, which could be used for solar power.
- There are two types of solar power technology: photovoltaic (PV) and concentrated solar thermal power (CSP).
- Installation costs and area requirements for the two technologies are roughly the same.
- 100 MW of capacity would cost ~[redacted](U.S. location estimate); [redacted] would buy approximately 21 MW of capacity.
- Ongoing operation and maintenance costs of CSP are almost triple that of PV.
- If a solar power plant is constructed, it would only provide power during the day, so existing power resources would still be required during periods of no sunlight.

16.2 Introduction and Assumptions

The Kandahar area receives a substantial amount of sun; approximately 6 kWhrs of solar energy per square meter (see Figure 6, below) every day.

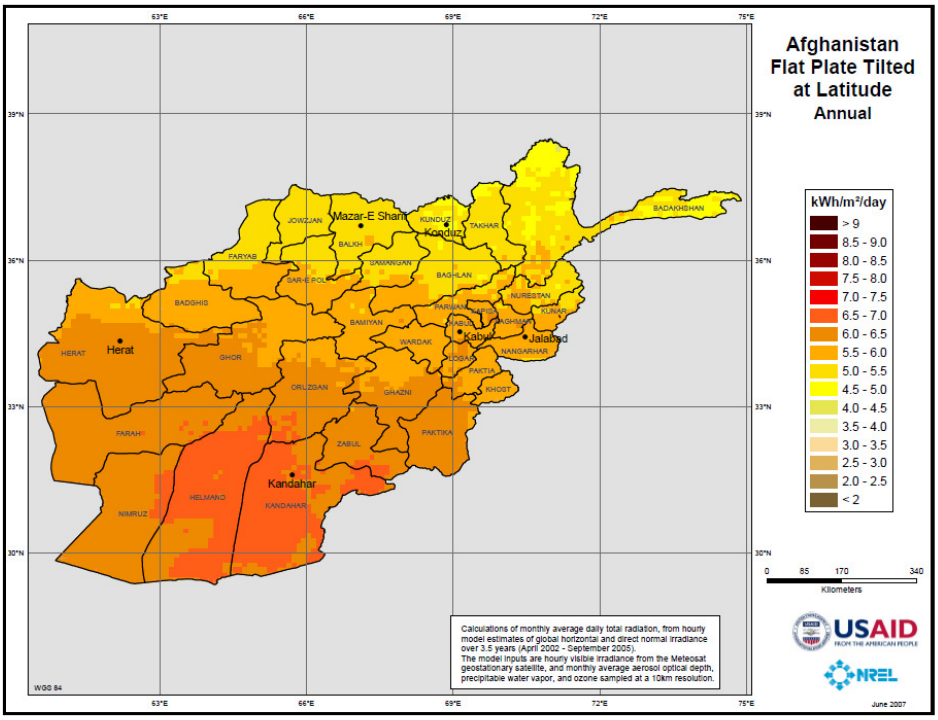

Figure 6: Afghanistan Insolation Map[51]

This section will describe options for using that solar power for electricity generation. It will describe the two dominant solar generation technologies and provide cost estimates and area requirements. Cost estimates are based on construction in a non-specific U.S. location with no unusual location impacts (e.g. urban construction constraints) or infrastructure needs (e.g. a project-dedicated interconnection upgrade cost). Since this project is contemplated in Afghanistan, appropriate country cost multipliers and cost-engineering judgment should be applied.

16.3 Technology Descriptions

16.3.1 Flat Panel Photovoltaic

A. Description

Flat-Panel Photovoltaic (PV) uses numerous arrays of ground-mounted, fixed-tilt PV modules which directly convert incident solar radiation into DC electricity, which can then be inverted to AC. Additional required system components include metal racks and foundations to support and align fixed panels, DC wiring, combiner boxes where individual strings of panels are connected prior to being fed into the inverters, DC-to-AC inverters, AC wiring, various switchgear and step-up transformers, and a control system (partly incorporated into the inverter control electronics) to monitor plant output and adjust the balance of voltage and current to yield maximum power. A typical array combines panels into 500 kW power units (which matches a common inverter size) to create the required output, and is extremely scalable. Additionally, tracker mechanisms can be employed to move the panel throughout the day, maximizing the collected solar radiation. Using these tracking mechanisms increases the system energy yield, reducing the land requirement for a given generation quantity. Tracking mechanisms add approximately 10-15% to the initial cost, and require ongoing maintenance.

[51] From NREL's solar resource map archive at: http://www.nrel.gov/gis/pdfs/swera/afg_pak/afg_10km_tilt.pdf; map is dated June of 2007.

Typical commercial flat-panel efficiencies are between 10% and 15%, and panel spacing uses only about 50% of the allocated area (to allow for maintenance and prevent panels from shading one another). Moreover, as much as 20% of power generated can be lost in the DC-to-AC conversion. So a square meter receiving 6 kWhrs/day of insolation (typical of the Kandahar area) will actually yield between 0.24 and 0.36 kWhrs/day of usable AC electricity.

It should be noted that a seemingly small change in panel efficiency would produce a large change in area required. For example, installing a 20% efficient panel, versus a 10% efficient panel, will reduce the land required for a given generation capacity by half. Similarly, increasing energy yield using tracking mechanisms also reduces land requirements.

A flat-panel PV system has a useful life (excluding inverters) of about 20 years. Figure 7 shows a typical large-scale PV array.

Figure 7: Solar Array at Nellis AFB (Single-axis tracking)

B. Cost

Flat-panel PV generation installation cost was estimated in late 2010 at between \$4.75M and \$6.05M per MW of capacity. Since installation costs for flat-panel PV plants have been going down 20% per year since 2009, a timely estimate is \$3.8M to \$4.85M per MW. Ongoing annual operation and maintenance (O&M) costs were estimated at between \$17k and \$26k per MW of capacity; these are for plants with no tracking devices. These estimates assume the lower bound is for a 150 MW plant; the upper bound is for a 7 MW plant[52].

Based on linear interpolation of the above estimates, 30 MW of capacity would cost \$140M. \$100M is estimated to develop 21 MW of capacity.

Ongoing annual O&M cost of a 30 MW plant would be \$[redacted]; for a 21 MW plant, [redacted]

C. Advantages

- Low-risk technology: Flat-panel PV technology is relatively mature and tested.
- Scalable: It is scalable, so capacity can be added with relative ease.
- Minimal maintenance: Maintenance is limited to cleaning the panels and inverter repair or replacement. (Adding a tracker system, with moving parts, would negate this advantage.)

[52] Derived from US Energy Information Administration's "Updated Capital Cost Estimates for Electricity Generation Plants", November 2010, available at: http://www.eia.gov/oiaf/beck_plantcosts/pdf/updatedplantcosts.pdf

[53] Ibid.

D. Disadvantages

- Large footprint: Flat panel PV requires significant land area; conservatively 1 hectare for each 250 kW of capacity (100 kW/acre). A 21 MW solar plant could require as much as 85 hectares (210 acres) of land. Figure 8 below illustrates the size of an 85 hectare area (basically a square box; 3,000 feet per side) compared to the Kandahar Airport.
- Inverter reliability: The inverter (an electronic device that converts DC to AC) is a key component to the flat-panel PV generation system. Inverter life spans are typically less than 10 years[54], and failure results in the loss of capacity until the inverter is replaced. Inverter replacement is included in the O&M costs listed above.
- Intermittent output: Flat-panel PV only generates during the day, and requires an energy storage solution to provide 24/7 power.

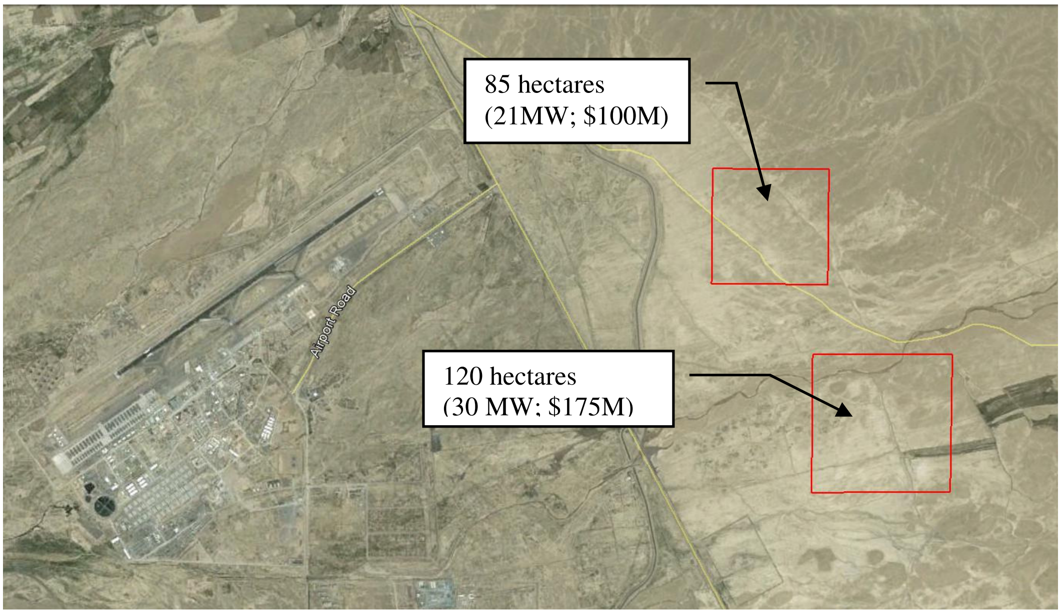

Figure 8: PV LAND REQUIREMENT EXAMPLES (2004 imagery)

16.3.2 Concentrated Solar Thermal Power

A. Description

Concentrated solar thermal power (CSP) generation involves concentrating solar radiation on a small area, then using the concentrated radiation as a heat source to heat a working fluid. The fluid is then used either directly to spin a turbine-generator, or used as a heat source to boil a fluid like water or pentane, which spins a turbine-generator. The power block uses typical auxiliary components for heat rejection, water treatment, water disposal, and interconnection to the grid. There are four current technologies using concentrated solar thermal power. The following section will briefly describe different technical approaches to CSP.

B. Dish Stirling

The Dish Stirling, or dish engine, system uses a single parabolic dish to focus solar radiation and heat a working fluid like hydrogen. The heat is converted to mechanical work in a closed-cycle heat engine (Stirling engine). The only commercial-scale Dish Stirling plant in operation (non-demonstration) is the 1.5 MW Maricopa Solar Plant in Peoria, AZ[55].

[54] The dominant inverter manufacturer in the U.S. (SMA) offers a standard warranty of 5 years. Further discussion of inverter reliability is at: http://www.nrel.gov/analysis/seminar/pdfs/2006/ea_seminar_jan_12.pdf

[55] See http://www.srpnet.com/environment/solar/maricopasolar.aspx

C. Solar Tower

A solar power tower uses mirrors that track the sun (heliostats) to reflect and concentrate solar radiation at the top of a tower. The working fluid is in a containment vessel at the top of the tower. Limited thermal storage has been designed into some solar towers, using molten nitrate salt as the working fluid. This salt is heated during the day, stored in tanks, and used overnight as a heat source for generation.

There are very few operational solar power towers. The largest solar tower is PS20, a 20 MW generation facility owned by Abengoa Solar in the Seville, Spain area. An 11 MW solar tower, also owned by Abengoa, operates next to PS20. PS10's construction cost was €35M (about $42M, using then-current exchange rates).

Figure 9: CSP Towers PS10 (foreground) and PS20

D. Fresnel Reflector

A Fresnel reflector uses many flat-mirrored strips to concentrate solar radiation on a tube containing a working fluid. This technology is just emerging from the demonstration phase. The largest plant using this technology is the Kimberlina Solar Thermal Energy Plant, in Bakersfield, CA (USA). It is a 5 MW demonstration plant.

E. Parabolic Trough

A parabolic trough uses a parabolically curved, trough-shaped reflector to reflect and concentrate solar radiation to a tube running parallel to the trough. The working fluid is contained in the tube. Parabolic trough technology is mature; there are several plants currently in operation. Two operational plants in Spain have similar insolation characteristics as the Kandahar area (6 kWh/m2-day), and their costs and outputs are listed below:

- Alvarado : 50 MW on 135 hectares; cost was €236M ($330M, or $6.6/MW).
- Andasol 1, 2 and 3: 50 MW each (total of 150 MW) on 153 hectares; cost was €900M ($1,125M, or $7.5M/MW).

Parabolic trough plants are typically augmented by a conventionally fired boiler to maintain a constant power output.

Because parabolic trough technology is the most mature technology, it is the only CSP technology recommended for further analysis and consideration.

Figure 10: Parabolic trough in Boron, CA (USA); part of Solar Electric Generating Station (SEGS)

F. Cost

Rough-order-of-magnitude cost for constructing a parabolic trough is approximately $4.6M/ MW[56]. Based on that estimate, 30 MW of capacity would cost $138M. $100M would buy 22 MW of capacity.

Ongoing annual O&M cost of a 30 MW plant would be $2.1M; for a 22 MW plant, $1.5M[57].

G. Advantages

- Low-risk technology: Parabolic trough concentrated solar power technology is relatively mature and tested.

H. Disadvantages

- O&M Expense: Because the technology uses conventional thermal power generation equipment (steam turbines), it requires similar O&M expenditure and technical expertise.
- Intermittent output: Parabolic trough concentrated solar power only generates during the day, and requires an energy storage solution or a conventionally-fueled augmenting boiler to provide 24/7 power.

[56] Cost is for a 100 MW plant in Arizona (USA), with no heat storage. See: http://www.nrel.gov/docs/fy11osti/49303.pdf. The US Energy Information Administration's "Updated Capital Cost Estimates for Electricity Generation Plants", November 2010 (used for estimating PV) estimates CSP **tower** costs at $4.08M/MW, and $64k/MW-yr O&M; these costs are within 11% of the parabolic trough estimates listed above.

[57] Ibid.

Technology	Cost for 30 MW:	30 MW Annual O&M:	Area req't for 30 MW[58]	$100M capacity:	$100M Annual O&M:	Area req't for $100M capacity
Flat-Panel PV	[redacted]		120 hectares	21 MW	[redacted]	85 hectares
Concentrated Solar			~100 hectares	22 MW		~75 hectares

Table 4: Summary of Solar Technologies and Costs

16.4 Energy Storage

If solar energy is to be used at night, it must be stored. Mature storage technologies[59] include:

- Pumped hydro
- Sodium-sulfur batteries
- Lead-acid batteries

Pumped hydro requires a source of water. Power generated during the day is used to pump water to a storage head tank; at night, the water flows out by gravity and spins a hydro-generator. About 20% of energy is lost during the storage process, and initial cost is between $2,500 and $4,300 per kW of storage capacity[60].

Batteries are 75-90% efficient (i.e. 10-25% of energy generated is lost during the charge/discharge cycle), and initial cost is between $1,700 and $4,900 per kW of storage[61]. Batteries have a finite lifespan, and can only be charged and drained a limited number of times. Spending more in initial capital cost buys a more efficient and longer-lasting battery.

Because storage solutions are so costly, the area's load profile should be clearly understood to enable proper sizing of the storage solution.

16.5 Conclusions and Recommendations

Since initial cost and land requirements are similar for PV and CSP, complexity and O&M costs drive the technology recommendation. PV's simplicity, robustness, and low ongoing O&M requirement make it a better choice for the Kandahar area than CSP.

Relying exclusively on solar power would require the construction, operation and maintenance of an energy storage system that would provide power during periods of no sunlight. The most cost-effective option is to use a solar plant to augment existing generation sources on the Kandahar grid.

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58 Area required for parabolic trough plants varies substantially based on plant design; these estimates use a planning factor of 85% of the PV requirement.
59 EPRI, "Electricity Energy Storage Technology Options", December 2010, p. 4-1.
60 Ibid. Page 4-22.
61 Ibid.

17.0 Tables of Near-Term Executable Options

A. The following three tables list options that are executable in the next 24 months:

Kandahar Diesel Replacement Options					
Item #	**Description**	**Time Frame†**	**EEC**	**Comments**	**Deliverable**
1	Kabul-Kandahar 220kV line	48-60 mo	[redacted]	Design & install.	2 NTP's required; one for bid package, and one for installation
2	Install Kajaki-2	48 mo		Adds 18MW to SEPS; unknown to Kandahar.	Functional unit #2
3A	Install PV/CSP	18-30 mo		Designs and installs PV and/or CSP.	2 NTP's required; one for bid package, and one for installation
3B	Install WTE	18-24 mo		Designs and installs WTE (max 3.5MW). Also requires a trash collection system implemented; not part of this estimate.	2 NTP's required; one for bid package, and one for installation
4	Herat-to-Kandahar 110 kV line installation	26-38 mo		Design and install 110 kV line from Herat to Kandahar.	2 NTP's required; one for bid package, and one for installation

† Estimated time frame to place project in service or complete task. Includes, as applicable, preparation of task orders, completion of studies and/or technical specifications, tender preparation, bid preparation by contractors, bid review and award, detailed engineering, procurement and construction.

Table 5: Kandahar Diesel Replacement Options

NEPS Options					
Item#	**Description**	**Time Frame†**	**ROM Cost**	**Comments**	**Deliverable**
1A	Identify obvious NEPS problems causing poor reliability and power quality	3 mo	[redacted]	This will require interviews with NEPS substation managers and others involved in the transmission and distribution system to document what they see is causing system outages and voltage excursions, such as which breakers they frequently reset, and areas that need automatic voltage control or automatic RPC.	Itemized list of projects to be performed and recommendation of who should perform them (DABS or USAID), along with any recommendations for improvements in how the NEPS is operated.
1B	Small system improvements based on findings of 1A	18 mo		This will be for NEPS improvements (discovered in 1A) such as dividing a load into several smaller loads, or replacing an undersized or damaged conductor. Some of the small improvements may be completed by DABS without USAID finances.	Installation of improvements recommended in 1A, all or part of work may be done by DABS.
2	NEPS system-wide stability/coordination study	22 mo		The NEPS system is presently very unstable and this is continually knocking the hydro generators offline, which is causing premature wear and tear on the component. This will identify the problems and propose solutions that are not obvious to the individual substation managers. This is also required before DABS can synchronize with imported power. This work could be part of a nation-wide transmission stability study as noted in the table in the Executive Summary. This task would logically build on the work done in 1A.	Coordination/stability report; also should have DABS modify the settings as noted.

3	Employ a Utility Management Company to assist/train DABS in Power Management	24 mo	TBD	Many of the above activities that are required to be performed are due to lack of management capability.	In-country experienced management team.
4A	Specify RPC to bring P-K to Chimtala line up to 450 MW	TBD	SOW and ROM in Process	Necessary to permit sufficient power transmission to Dasht-e-Barchi substation during the winter season.	Concept Design Package for RPC
4B	Install RPC to bring P-K to Chimtala line up to 450 MW	18-30 mo	$TBD by 4A. Screening-level estimate of [redacted] is based on North American costs.	This must be done or there will not be sufficient power available to Dasht-e-Barchi substation during the winter season. Necessary to permit increases in the amount of power imported from Uzbekistan and Tajikistan.	Installed RPC to bring P-K to Chimtala up to 450 MW as detailed in item 4A
5A	NEPS SCADA improvements study	8 mo	[redacted]	The NLCC needs to be utilized to provide control as well as monitoring of NEPS systems. This will help in allowing DABS to synchronize with the imported power systems.	NEPS SCADA report to improve functionality of the NLCC.
5B	NEPS SCADA Improvements	TBD	TBD	Additional SCADA controls for the NEPS portion of the NLCC system.	Installed NEPS SCADA controls system as detailed in item 5A.

Table 6: NEPS Options

† Estimated time frame begins at NTP.

SEPS Options					
Item #	**Description**	**Time Frame†**	**EEC**	**Comments**	**Deliverable**
1A	Identify obvious SEPS problems causing poor reliability and power quality	6 mo	[redacted]	This will require interviews with SEPS substation managers and others involved in the transmission and distribution system to document what they see is causing system power outages and voltage excursions, such as which breakers they frequently reset, and areas that need automatic voltage control or automatic RPC.	Itemized list of projects to be performed and recommendation of who should perform them (DABS or USAID)
1B	Small system improvements based on findings of 1A	26 mo	[redacted]	This will be for SEPS improvements (discovered in 1A) such as dividing a load into several smaller loads, or replacing an undersized or damaged conductor. Some of the small improvements may be completed by DABS without USAID finances.	Bid/design packages (or recommendations for DABS) to implement improvements based on item 1A.
2	SEPS system-wide stability/coordination study	14 mo	[redacted]	The SEPS system is presently very unstable and this is continually knocking the hydro generators offline, which is causing premature wear and tear on the component. This will identify the problems and propose solutions that are not obvious to the individual substation managers. This process should not include any areas north of Durai Junction, especially the 110 kV line serving Sangin South and Kajaki Dam.	Coordination/stability report; also should have DABS modify the settings as noted.

† Estimated time frame to place project in service or complete task. Includes, as applicable, preparation of task orders, completion of studies and/or technical specifications, tender preparation, bid preparation by contractors, bid review and award, detailed engineering, procurement and construction.

Table 7: SEPS Options

18.0 Summary & Recommendations

A. During the preparation of this report, several key points became evident.

1. There is insufficient generation and import capability to meet peak demand in Afghanistan.
2. Tajikistan and Uzbekistan, Kabul's major sources of imported power, will not allow their systems to be synchronized with each other, or with Afghanistan's indigenous power. This creates a substantial barrier to reliable grid development with any imported power.
3. Productive use of gas at the Sheberghan gas fields requires the construction of a sweetening plant, which is currently unplanned and unfunded. The only sweetening plant currently planned is to supply a fertilizer plant, and does not have sufficient capacity to supply a power plant.
4. Existing Afghan hydro resources are currently underused. Output of these relatively low-O&M/fuel-cost sources could be increased through upgrading control systems, providing needed maintenance on reservoirs and other hydro infrastructure, integrating controls into the NLCC and determining whether existing hydro facilities can be expanded for increased output.

B. The following is a synopsis of additional conclusions and recommendations.

18.1 Conclusions and Recommendations (NEPS—SEPS connection)

A. The proposed connection of the NEPS and SEPS systems is technically viable—it can be built.
   1. Disadvantages:
      - Exacerbates Kabul's short-term supply shortfall.
      - Long transmission line, therefore exposed to insulator flashover and structural damage.
      - Adds complexity and risk to the Kandahar power system, by increasing the number of Kandahar un-synchronized supplies from two to three.
   2. Advantages:
      - Supports the long-term power grid vision.
      - Allows potential electrification of ~400,000 urban residents along the Ring Road.

18.2 Conclusions and Recommendations (Potential New Power Sources)

A. Constructing a 200-MW gas-fired power plant at Sheberghan:
   1. Requires construction of a gas-sweetening plant to make the fuel usable.
   2. Requires investment in wells and gas-conditioning facilities.
   3. Is an outstanding opportunity for an economical base-load power plant in NEPS.
   4. Should include consideration of combined-cycle technology.
   5. Should be constructed near Sheberghan, minimizing the length of gas transport lines and taking advantage of transmission lines feeding the sweetening plant and compressor stations.

B. Constructing additional run-of-river Sarobi hydroelectric power plants:
   1. Is executable after verifying older feasibility plans
   2. Insufficient data is available to assess the feasibility of a 200-m (near-Hoover-Dam size) dam and associated power plant.

C. Imports:
   1. Tajikistan and Uzbekistan do not allow their power to be synchronized with each other or with Afghanistan, severely limiting flexibility in use.
   2. The 300-MW Tajikistan PPA does not help Afghanistan meet winter-peak loads; it limits power export at that time due to supply shortages.
   3. Although there is a 300-MW PPA with Uzbekistan and a 300-MW PPA with Tajikistan, only 225 MW from each source can be transmitted to Kabul, since line capacity is constrained to 450 MW (after the successful implementation of RPC).

18.3 Conclusions and Recommendations (Transmission Requirements)

A. Uzbekistan to Mazar-e-Sharif
   1. Integrate analog and digital SCADA points into the National Load Control Center via SCADA to allow supervisory oversight and override control.

B. Sheberghan Spur
   1. When the transmission line is installed, install RPC on the Sheberghan 220-kV bus to control the bus voltage rise under light-load conditions.
   2. Install under/over-voltage relays to control the RPC.

3. Integrate RPC controls and other analog and digital SCADA points into the National Load Control Center via SCADA to allow supervisory oversight and override control.

18.4 Conclusions and Recommendations (Tajikistan Line)

A. Install switched shunt reactors (RPC) at the Kunduz 220-kV bus to control voltage rise of a lightly loaded line.

B. Install under/over-voltage relays to control the RPC.

C. Integrate RPC controls and other analog and digital SCADA points into the National Load Control Center via SCADA to allow supervisory oversight and override control.

D. Obtain agreement from both Uzbekistan and Tajikistan that their respective systems can be paralleled at the Pul-e-Khumri substation 220-kV bus.

E. Obtain agreement from both Uzbekistan and Tajikistan to integrate SCADA analog and digital points into Uzbek, Tajik and Afghan National Load Control Centers.

18.5 Conclusions and Recommendations (RPC)

A. Integrate RPC system controls and other analog and digital SCADA points into the National Load Control Center via SCADA to allow supervisory oversight and override control.

B. Study each transmission line to determine applicability of RPC to achieve optimal power transfer ratings. In every situation where RPC is recommended, a brief study will be required to scope the amount and location of RPC to be installed.

18.6 Conclusions and Recommendations (Jalalabad—NEPS Integration)

A. Options to NEPS integration:
   1. 25-MW diesel generation, $40M ROM cost, 30-50 cents per kWh O&M cost, including fuel.

   2. Dredge Darunta reservoir; install additional generator bays to achieve 40 MW of output. (This requires a feasibility study. The study would also encompass river flow, to see if the Kabul River's minimum flow will sustain 40-MW generation output.)

   3. Local solar combined with wind 30 km north and 30 km east of Jalalabad ($60M ROM).

   4. Ramp up supply to industrial park, as necessary.

B. Implications of Jalalabad–NEPS integration:
   1. Advantages
      - Significantly increases reliability of the Jalalabad system
      - Increased voltage control of the Jalalabad system
   2. Disadvantages
      - Further exacerbates Kabul-area generation shortfall by approximately 25 MW in the near-term
      - Introduces reduced reliability in the Sarobi area due to 80 km of additional exposure to transmission line faults.

18.7 Conclusions and Recommendations (Diesel Alternatives)

A. Powering Kandahar with diesel is unsustainably expensive.

B. Scalable distributed renewable energy offers substantial promise.

C. Implement solar PV and WTE on a pilot basis.

D. Expedite the installation of the 17-MW Kajaki-2 turbine, and supporting transmission line.

18.8 Conclusions and Recommendations (Distribution Expansion Impacts)

A. Most of the country has demand in excess of supply, so expanding distribution (without expanding generation) exacerbates the shortage of power.

B. Expand distribution in Kabul and Kandahar where there is evidence of overloaded feeders or substation transformers.

C. Conduct targeted refurbishment of existing generation and distribution controls.

18.9 Conclusions and Recommendations (Power Quality and Stability)

A. Synchronize all Afghan grid-connected generation with import sources.

B. Perform stability studies on the existing and proposed Afghan transmission and generation systems to identify improvements necessary to minimize loss of generation due to system disturbances.

C. Analyze system fault data to determine likely cause of faults as a first step to reducing their frequency or duration.

D. Enable a more-thorough system data historian [load data for all substations, transmission lines, grid-connected generators, substation transformers; distribution feeders; monthly peak demands (MW and MVAR)].

E. Enable an outage historian to track system outages, location, duration, estimated customer count affected, primary cause and secondary cause.

F. Implement under-voltage and under-frequency load-shedding schemes to automatically and quickly respond to imminent system collapse.

G. Implement over-voltage protection schemes to automatically and quickly adjust generation and shunt reactors to keep voltage within acceptable limits.

H. Review, update and upgrade transmission, generation, and distribution-system fault protection schemes (relay coordination) to help prevent cascading fault-caused outages.

I. Adopt and specify power quality standards that are appropriate to Afghanistan's emerging transmission grid and distribution system.

J. Integrate distribution substation analog and digital SCADA points into the National Load Control Center via SCADA to allow supervisory oversight and override control.

K. Upgrade controls of substation transformer Load-Tap-Changers, regulators and switched shunt devices to enable monitoring and control from the National Load Control Center.

L. Implement condition-based maintenance practices.

M. Increase the number of analog and digital SCADA points accessed from the National Load Control Center.

N. Enable spinning reserve (10% of the required power).

O. Study the distribution system to identify opportunities for VAR control.

18.10 Conclusions and Recommendations (300-MW Turkmenistan Import)

A. The proposed import of 300-MW of power to Kandahar from Turkmenistan is technically feasible, based on very preliminary results. More sophisticated modeling must be performed to ensure dynamic criterion will be met and to size the RPC system.

B. Disadvantages:
   1. Expanding the line beyond Kandahar or increasing import beyond 300 MW is not technically feasible.
   2. Adds complexity and risk to the Kandahar power system, by increasing the number of Kandahar un-synchronized supplies from two to three.
   3. Significant substation investment in Herat needed to enable continued use of Turkmen supply.

C. Advantages:
   1. Reduces Kandahar dependence on very expensive diesel generation.
   2. Allows serving distribution load that could not otherwise be served from Kajaki or Kandahar diesel sources alone.

18.11 Conclusions and Recommendations (Solar Power)

A. If a solar power plant is to be built, construct a PV, vice CSP, solar plant. Initial cost is very similar, and O&M expense is much less.

Due to the expense of energy storage, use solar power to augment hydro and diesel, but not as a sole source of electricity.

USAID/Afghanistan
U.S. Embassy Cafe Compound
Great Masood Road
Kabul, Afghanistan
Tel: 202.216.6288
http://afghanistan.usaid.gov