Afghanistan Resource Corridor Development: Power Sector Analysis

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John Irving & Peter Meier

Contents

Exchange rate

1 US dollar = 49.2 Afghani

Calendar Conversion

Gregorian year	Afghan year
2008	1386
2009	1387
2010	1388
2011	1389
2012	1390

Abbreviations and Acronyms

AEIC	Afghanistan Energy Information Center
AFISCO	Afghanistan Iron & Steel Corporation
ADB	Asian Development Bank
ARTF	Afghanistan Reconstruction Trust Fund
B/B	back-to-back
CAS	Central Asian States (Turkmenistan, Tajikistan, Uzbekistan, Kyrgyzstan and Kazakhstan)
CCGT	combined cycle gas turbine
CDM	Clean Development Mechanism
DABS	Da Afghanistan Breshna Sherkat (Afghanistan Power Company)
ERR	economic rate of return
FIRR	financial rate of return
FS	feasibility study
FSU	Former Soviet Union
GDP	gross domestic product
GHG	greenhouse gas
GHG	greenhouse gas
GNI	gross national income
HH	household
HVAC	high voltage alternating current
HVDC	high voltage direct current
ICE	Inter-ministerial Commission on Energy
IDC	interest during construction
IFI	international financial institution
IPCC	Intergovernmental Panel on Climate Change
LRMC	long run marginal cost
MEW	Ministry of Energy and Water
MoM	Ministry of Mines
MJAM	China Metallurgical Group Corporation
mmBTU	million British thermal units
MoU	Memorandum of Understanding
MV	medium voltage
NCM	million cubic metres
NEPS	North-eastern Power System
PPP	private-public partnership
RCD	Resource Corridor Development
RoW	rights-of-way
SS	substation
SEPS	South-eastern Power System
SIL	surge impedance loading
T&D	transmission and distribution
TA	technical assistance
UAP	Uzbekistan-Afghanistan-Pakistan (HVDC electricity trade project)
USAID	Unites States Agency for International Development
WTP	willingness-to-pay

Executive Summary

1. This report examines the power sector implications of the Resource Corridor Development (RCD) proposal. The mining developments that form the core of the RCD are not just potential consumers of power, but also a potential *source* of power for Afghanistan, since the large generation projects necessary to serve the extraction and processing of ores can readily be sized to meet more than just the mining project demand. Significant deposits of coal and reservoirs of gas make such generation possible.

2. This has potentially important impacts not just on the generation expansion plan, but also on the configuration of the transmission system. In particular it represents an opportunity to integrate with and thereby diversify Afghanistan's power supply mix, which over the past few years has become heavily dependant on imports from the Central Asian States (notably Uzbekistan), as well as from Iran (to serve the demand in the Herat area).

3. Afghanistan's strategic location makes it an important player in the many proposed trade projects to bring energy from the energy-rich countries to its north and west, to the energy hungry countries to its east and south, including major gas pipeline projects as well as electricity trade. These may bring potential transit fee foreign exchange earnings, as well augment Afghanistan's energy supply (of which proposals for increased electricity trade from the CAS to Pakistan are directly relevant to this report).

4. However, the Afghan power sector is faced with a complex set of issues largely associated with the difficult security situation and the country's high dependence on power imports from the larger neighbouring power systems: in 2011, the Northeast Power System (NEPS) that serves the North and Kabul imported 77% of its requirements. The exporting countries include Iran and the four former Soviet Union Central Asian (CAS) countries, Kyrgyz Republic, Tajikistan, Turkmenistan and Uzbekistan.

5. The only new domestic generation project in the last five years (the 105 MW diesel project at Tarakhil completed in 2010) has been little used for reasons of high operating cost and fuel shortages. Hydro is a potential supply option, but feasibility and costs are uncertain. The 2004 Master Plan recommended the development of two larger hydro projects (Surobi-II, 180 MW, and Bagdara, 280 MW), but most of the studies for potential hydro candidates date to the 1980s, and some require more comprehensive feasibility studies before costs, hydrology, and environmental impacts can be reliably stated. There is similar uncertainty about the prospects for development of the Sheberghan gas field for power generation: there may be other competing uses for this gas (fertilizer industry, households) if the current estimates of reserves can be confirmed. The gas is sour, requiring treatment before it can be used for power generation: whether CCGT or gas engines is the best technology choice requires further study.

6. The RCD Project may offer Afghanistan an opportunity to generate and transmit power from its domestic coal and gas resources while also undertaking the development of hydro capacity near Kabul. The immediate concern is to ensure that the proposal of MJAM (the Chinese developer of the Aynak copper mine south of Kabul) to build a coal-fired power plant at Ishpushta will make available at least 200 MW capacity for domestic use in addition to its own requirement of about 150 MW. Accordingly it will be necessary for the associated 220 kV line from Ishpushta to the copper mine at Aynak to be appropriately interconnected into the Afghan power system. There is also an opportunity to utilize and extend the new 220 kV lines so they form the basis for a 220 kV ring around Kabul. The MoU with MJAM states that the electricity price for the power project will be by mutual agreement of the Parties, and there are understandings that a PPA should be negotiated, but such negotiations do not seem to have started yet. The expectation is that the cost to NEPS would be significantly below the cost of Uzbek gas-based imports, currently at 7.5 UScents/kWh.

7. The impact of the AFISCO[1] iron ore project is more uncertain. It would not likely build a coal-fire generation project for its own use, and if the project is limited to just ore mining and shipping, its electricity needs would be small (about 50 MW). If steel is to be manufactured, then the project may be either be a net electricity exporter (if it uses the blast furnace conversion process, because town gas from coking and producer gas from the blast furnace can be used for generation) or a net gas importer (if it uses the DRI process), or both (if there were surplus natural gas it might supplement the producer gas from the blast furnace to generate electricity in a CCGT).

8. It is important to recognise that all the neighbouring power systems operate asynchronously, and through their exports oblige Afghanistan to operate six separate power systems each synchronised with its neighbouring supplier. While this has helped Afghanistan grow its electricity sales over the last five years, asynchronous supplies limit the opportunities to interconnect and expand the power network in a rational way. Of the five main geographically separate power networks in Afghanistan, the North Eastern Power System (NEPS) is the largest. They could all be interconnected if the respective CAS country sources decided to operate either in synchronisation or agreed to interconnection with each other through high voltage direct current (HVDC) links. The NEPS currently supplies part of Kabul city over long 220 kV links from Tajikistan and Uzbekistan. Other parts of Kabul are supplied from various local hydro and diesel generators which are currently not synchronised with the NEPS. Under a USAID sponsored project it is expected the NEPS will be interconnected with the Kandahar-based South-eastern Power System (SEPS) in the future.

9. Further investment in transmission cannot avoid the synchronization issue. Afghanistan's contract with Uzbekistan expressly forbids DABS from synchronising domestic generation plant with the Uzbek system. Likewise the contract with Turkmenistan stipulates that HV transmission facilities in Afghanistan must have "identical technical characteristics". In effect this means that the main load centre in Kabul is currently supplied from two separate sources; part from the Uzbek system and part from is own domestic generation. Other smaller load centres adjacent to the Uzbek

[1] Afghanistan Iron & Steel Consortium, led by the Steel Authority of India.

to Kabul transmission lines are similarly constrained to use their own diesel or smaller generation without access to the cheaper Uzbek power. Therefore, in the first instance it is essential that Afghanistan adopts a Grid Code acceptable to the CAS countries to enable Da Afghanistan Breshna Sherkat (DABS, the national electricity utility) to synchronise its in-country generation with the imported power systems.

10. Given the asynchronism issues, the long distances involved (coupled with the inherent operational constraints of long HVAC transmission lines), and the power transit opportunities, there is no doubt that HVDC systems in some form or another will be part of any future Afghanistan transmission system. A current proposal for achieving the interconnection is by installing HVDC Back-to-Back (B/B) systems located in Afghanistan to enable DABS to develop its own synchronous system independently from its neighbours. However this approach is costly and could leave Afghanistan with a significant stranded HVDC B/B asset if the neighbouring systems did eventually resynchronise with each other. Moreover it would not take advantage of the much lower construction cost of HVDC transmission and other technical advantages of operating in parallel with HVAC after having made the significant investment in HVDC/HVAC conversion facilities.

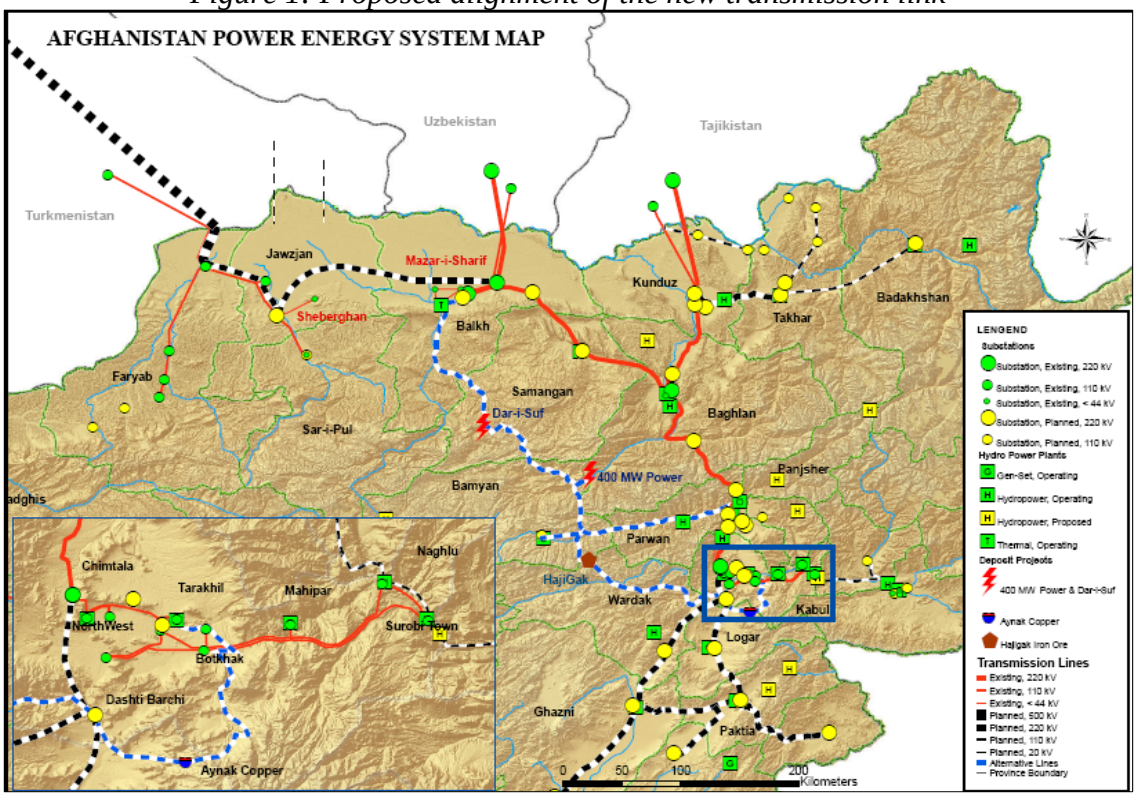
11. Various other HVDC power transit projects have been proposed to bring electricity generated in the Central Asian States to Pakistan, with some proportion made available to Afghanistan at Kabul. The Uzbekistan-Afghanistan-Pakistan Electricity Supply and Trade Project (UAP) would deliver 100 MW (915 GWh) to DABS at an HVDC inverter substation North of Kabul and 900 MW to Pakistan in the Peshawar area. The CASA-1000 project would similarly deliver up to 300 MW of surplus hydro power from Tajikistan and Kyrgyz Republic, also by HVDC to Kabul, and a further 1,000 MW to Peshawar. Both projects offer various technical advantages to Afghanistan particularly in terms of how they may be used to deal with the synchronisation and instability problems, and how they can supply a diversified source of bulk power over long distances to the major load centre in Kabul.

12. However, the financial and economic aspects of these import/transit schemes need further analysis, particularly to ensure equity among the participants. Given the many uncertainties about these projects, there are considerable risks in making power sector investment decisions now that may prove later to be counterproductive. Afghanistan should not be obliged to make significant front-end investment in transmission facilities for power transit operations unless they are backed by legally enforceable long term power purchase and transit contractual agreements.

13. The main recommendation of this report is to forgo at this time the proposal to duplicate the existing 220 kV line from Pul-e-Khumri to Kabul (via the Salang Pass). Instead it is proposed to build a new north-south 220kV line (or possibly a 500 kV line operated initially at 220 kV) from the northern city of Mazar-e-Sharif. (Figure 1). The line would traverse through Bamyan township, connecting to the Ishpushta 400 MW power station en route to Kabul South East substation, and thence to the Aynak copper mine. As the first step in its development it is also proposed to complete the 220kV loop around Kabul by connecting Aynak back to Tarakhil power station to enable the Aynak mine to use Tarakhil for start-up purposes. There should be provision in the

design of the 220 kV north-south line for supplying power to the proposed iron ore mine near Bamyan, and interconnecting other potential coal fired stations in the area in the future. The technical details of such an approach will of course await the outcome of further dialogue with MJAM power designers, but this approach would have the advantage of facilitating additional generation resources at Sheberghan gas fields and providing greater diversity and security of supplies to Kabul as well as relieving potential overloading on the existing Mazar-e-Sharif to Pul-e-Khumri section of the 220 kV transmission line.

Figure 1: Proposed alignment of the new transmission link



14. Our cost estimates for this proposed alignment is shown in Table 1. The total estimate of $184 million, based on costs for lines and substations contracted under ICB procedures, would be offset by the savings from the ADB proposed north-south project.

Table1: Preliminary cost estimates

Phase	Scope of Work	Dependence on other Developments	US$ m
1	MJAM builds 220 kV line from 113 MW Tarakhil DPS to Aynak	This line will would be required to provide the initial power to the Aynak mine possibly from the Tarakhil Diesel power station, though not part of the current contractual obligation of MJAM.. The implementation arrangements, including responsibility for maintenance and the timing of the transfer of ownership the DABS will need negotiation.	32.2
2	MJAM builds the 220 kV line from 400 MW Ishpushta plant to Aynak mine	This line is required under the Ministry of Mines contract with MJAM together with an obligation to supply DABS at both Bamyan and Dashti-Barchi. It is noted the supply to Bamyan would also be required to house the MJAM workforce associated with the Ishpushta mine and power plant	72.4
3	DABS builds line from Mazar-e-Sharif to complete north south route	This project would proceed when either Sheberghan gas fired power plant is available; or if power from Turkmenistan is available under a new import contract	65.9
4	220 kV ring around Kabul completed when/if CASA project proceeds	This project could be built either as part of the CASA project to enable an HVDC converter supply to be interconnected with Tarakhil and Chimtala, or as part of Bagdhara hydro project development.	13.5

15. Transmission alignments need careful assessment. The proposal to build a duplicate 220 kV line across the Salang Pass appears to be motivated by the fact that it is demonstrably possible to do so and would be adjacent to a major road. While the existing 220 kV line is undersized for bulk transit of power, there are alternative routes that have the advantage of providing a more direct source of power from domestic generation plant while providing the Kabul power system greater security through diversity. Thus rather than duplicate the capacity of the line with a parallel 220 kV line along the same route, to reduce congestion it would be better to reserve the route for a future HVDC line (e.g. the CASA project) to provide bulk power to Kabul or transit power en route to Pakistan.

16. On the other hand the UAP project has identified a parallel north-south route which could also be used for new 220/500 kV line providing an opportunity to build substations en route and interconnecting with the proposed MJAM line. It should be recognised that while there are advantages in building transmission lines near roads, cross country alignments can significantly shorten routes and thereby reduce costs. In this regard Afghanistan has unique topographical features that facilitate cross country transmission construction. There is little vegetation, there are many hills offering the prospect of long spans, and cross country access without proper roads is feasible for construction especially when carried out in conjunction with helicopter operations.

17. The resource corridor coal projects will increase carbon emissions, but greenhouse gas (GHG) emissions per capita or per $ of GDP will remain among the world's lowest. By 2025, the resource corridor projects would increase per capita emissions from the present 0.10 tons CO_2/capita to 0.18 tons/capita (based on a 1.5% annual population growth rate): this compares to a 2009 *world* average of 4.4 tons CO_2/capita. Supercritical coal technology would in principle provide higher efficiency (typically 42-43% efficient compared to 36-37% in the sub-critical units that can be expected) and lower GHG emissions, but the minimum unit size is around 600 MW, and therefore not suitable for Afghanistan's incremental power needs at this stage. No supercritical coal project in Asia is smaller than 2 x 500 MW. Efficiency can be incentivised by a normative heat rate requirement in the power purchase agreements for sales to DABS. Moreover, equivalent improvements in GHG emissions can be achieved by reducing technical losses in T&D with far greater benefit for the system as a whole.

18. Finally we note that the present level of T&D losses (estimates range from 30-40%) is unacceptable. Reducing T&D losses, and particularly non-technical losses, remains an immediate priority, with high net economic benefits as well as significant reductions in GHG emissions. The benefits accrue regardless of the choice of supply or transmission options, or of the uncertainties of the load forecast.

1. Background

1.1 Context[2]

1. The Afghan economy must find new sources of growth if the transition and long-term stability are to succeed. The extremely high level of current annual aid (estimated at $15.7 billion in 2010[3]) is roughly the same dollar amount as Afghanistan's GDP and will not be sustained at such levels post 2014. The direct impact of transition will exert a drag on the overall economy at a time when growth is vitally needed to cope with fiscal and demographic pressures. Growth, under reasonably optimistic scenarios, is projected to fall from a ten-year average of over 9% to between 5-6% in 2011-18. By 2021/22, the Government of Afghanistan (GoA)'s financing gap is projected to be 25% of GDP. Unemployment and underemployment, already at 8% and 48% in 2009/10 will rise just as the labour force is expanding by 300,000 new entrants per year.

2. The resources sector offers a window of opportunity, but also challenges. While the potential of Afghanistan's mineral resources has long been known, recent years have seen the first steps in decades to realize it. Although the absence of systematic and detailed geological studies for 25 years make it difficult to place a value on the country's deposits, it seems likely that it amounts to at least several hundred billion dollars. In 2008 mining rights at Aynak, a large-scale copper mine in Logar province, were awarded to a consortium led by MJAM (a joint venture of China Metallurgical Group Corporation and Jiangxi Copper Corporation): MJAM has also proposed a 300-400 MW mine mouth coal fired power plant. In November 2011 three blocks of mining rights at HajiGak, a large iron-ore deposit, were awarded to AFISCO (Afghan Iron and Steel Consortium)[4] and one block to Kilo Goldmines of Canada (Figure 1.1). Oil in Amu Darya is expected to come on stream in 2012 and gas in Sheberghan is expected to start production within five years. Successful development of these mining resources, together with the associated power generation and the oil and gas blocks, will bring not only significant revenue and growth, but could create a demonstration effect that would unlock much broader potential in the future if security stabilizes.

3. To realize the mining sector's full potential, hard and soft infrastructure must be combined over time along a 'resource growth corridor' – which has been defined as a sequence of investments and actions to leverage a large extractive industry investment, in infrastructure, goods and services, into viable economic development and diversification in a defined geographic area. A resource growth corridor aims to exploit resources' potential while escaping resource dependency. It represents a combination

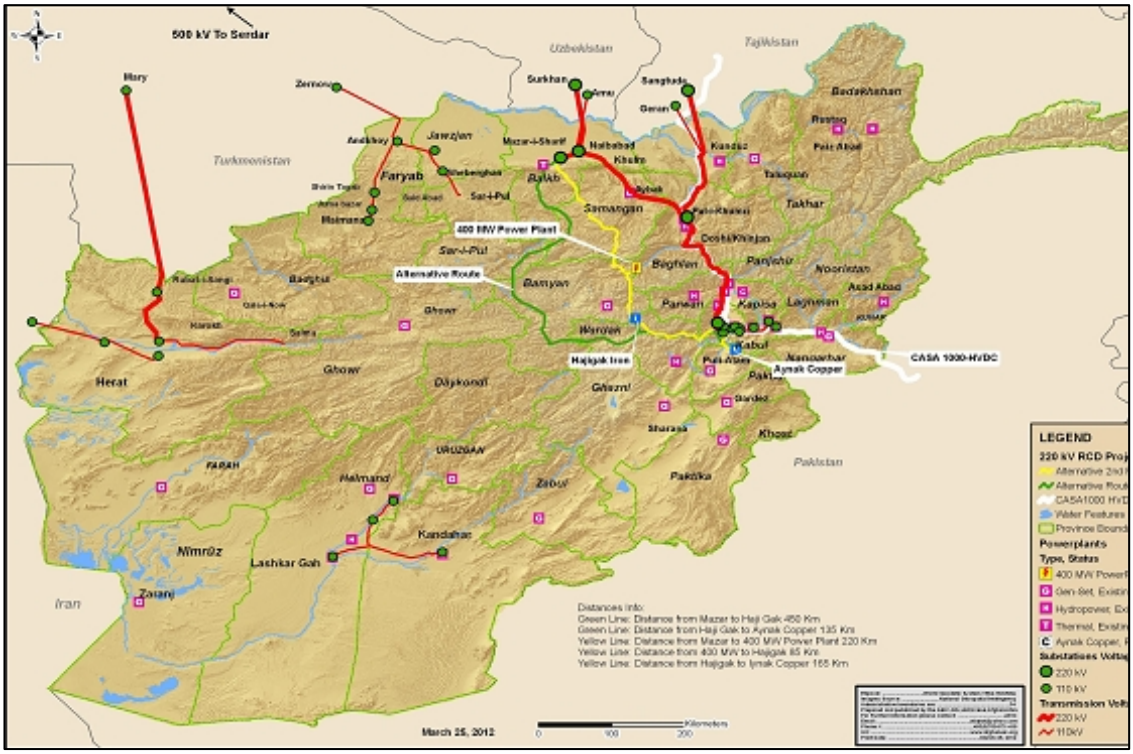
[2] This is section is a summary of the World Bank Project Concept Note: *Support for Programmatic Resource Growth Corridor Development.*

[3] This amount includes security aid. Civilian aid is approximately $6 billion.

[4] The consortium is led by the Steel Authority of India.

of efforts to leverage a large extractive industry investment, and its requirements for infrastructure and goods and services, into viable economic development and diversification. For a number of reasons, especially in a low-income country, economic linkages between mining and the rest of the economy will not naturally occur through market forces. When the barriers to wider benefits are not addressed, the local economy is unlikely to take advantage of the opportunities to supply goods and services to the mine or other resource-based investment, or take advantage of any potential to use its products and its associated infrastructure. In particular, there is a need to rapidly prepare the fledgling Afghan private sector to reap the downstream benefits generated by the large mining projects and to generate jobs.

Figure 1.1: RCD projects



1.2 Objective

4. This report examines the power sector implications of the Resource Corridor Development (RCD) proposal. The mining industry is not just a major consumer of power, but also a potential source of power for the country as a whole, since the large generation projects necessary to serve the extraction and processing of ores can readily be sized to meet more than just the mining project demand, exploiting the scale economies. Significant deposits of coal and reservoirs of gas make such generation possible.

5. This has potentially important impacts not just on the generation expansion plan, but also on the configuration of the transmission system. In particular it represents an opportunity to diversity Afghanistan's power supply mix, which over the

past few years has become heavily dependant on imports from the Central Asian States (notably Uzbekistan), as well as from Iran (to serve the demand in the Herat area).

1.3 The mining projects

6. The Aynak copper mine, about 30 km in a direct line from a planned 220 kV substation at Dasht-e-Barchi (on the southern outskirts of Kabul), is the first major mine likely to see production, probably after 2014. According to the concession agreement, subject to a detailed feasibility study, MJAM would construct a railway from Aynak copper mine in Logar province south of the capital city of Kabul to the border towns of Torkham to the east and Hairatan to the north. However, according to the RCD Railway Development Plan[5], it seems unlikely that such a line would be economically justified for the Aynak project: The most likely option is to smelt the ore into copper ingots, which can be exported using the significant backhaul capacity of local trucking resources.

7. Indeed, the amount and cost of power from the MJAM project is still uncertain**.** MJAM has undertaken to build a somewhat larger coal-based power generation project than necessary for its own requirement (about 150 MW): an additional 100-250 MW would appear possible for domestic consumption, subject to confirmation of the coal resource.[6] Such a larger plant would of course require it to be integrated within the NEPS network and to be synchronised in accordance with a Grid Code acceptable to CAS power exporting countries. The Memorandum of Understanding (MoU) with MJAM states that the price will be by mutual agreement of the Parties, and there are understandings that a power purchase agreement (PPA) should be negotiated, but such negotiations seem not to have started yet. The expectation is that the cost to NEPS would be significantly below the cost of Uzbek gas-based imports, currently at 7.5 UScents/kWh.

8. The impact of the AFISCO iron ore project is similarly uncertain.[7] It would not likely build a coal plant for its own use, and if the project is limited to just ore mining and shipping, its electricity needs would be small (about 50 MW). If steel is to be manufactured, then the project may be either be a net electricity exporter (if it uses the blast furnace conversion process, because town gas from coking and producer gas from the blast furnace can be used for generation) or a net gas importer (if it uses the DRI process), or both (if there were surplus natural gas it might supplement the producer gas from the blast furnace processing to make electricity in a CCGT).

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5 Harral, Winner, Thompson, Sharp, Klein, *Afghanistan Resource Corridor: Railway Development Plan*, Report to World Bank, 13 April 2012.

6 The precise capacity of the project has yet to be proposed by MJAM. We refer in the text to a 400 MW plant as its indicative size.

7 Similarly, it seems unlikely that the AFISCO project would need a new railway line in the short to medium term, and the Indian sponsors of the Hajigak mines have stated publicly that they intend to use trucks to move mine products to Gwadar for export (see RCD Transportation Study, *op.cit.*)

2. Afghanistan's Power Sector

2.1 The power system

9. As depicted in Figure 1.1, at present there are within Afghanistan three distinct geographically separate transmission networks

- The Northeast Power System (NEPS): Nangarhar/Kabul/Parwan/Ghori/Balkh (presently supplied by existing hydropower projects, a minor share from diesels, and a major share from imports).
- The Southeast Power System (SEPS): Kandahar and surrounding region (presently supplied by existing hydropower projects).
- Herat (presently supplied by imports from Iran and Turkmenistan).[8]

In addition, several towns (such as Aybak and Ghazni) have their own standalone diesel plants and limited distribution systems.

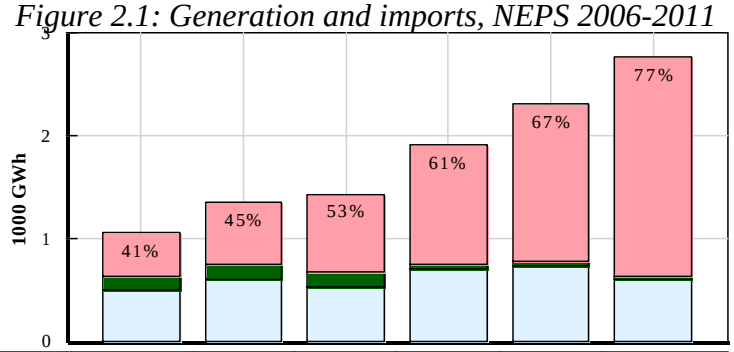
10. As also shown in Figure 1.1, the RCD mining projects lie within proximity of the NEPS system. But NEPS, with the completion of the Sheberghan-Naibabad 220kV link electrically and capable of being fully inter-connected, is not in fact operated as a single system, but as four isolated networks, because it is supplied from the three CAS countries that are currently not synchronised with each other. The fourth part of the NEPS that supplies the southern part of Kabul is served by domestic generation which is also not allowed to synchronise with the Uzbek system. How these problems can be overcome is one of the major problems taken up in later sections of this report.

2.2 Electricity demand and load forecasts

11. In the past few years, electricity consumption has grown rapidly. While reliable sales figures are not available, there exists relatively good information on total national generation (and imports), which grew from 1,291 GWh in 2006 to 3,088 GWh in 2011, an annual growth rate of 19%. The NEPS– which covers the Northeast, North, Kabul, and the areas immediately to the South and east of Kabul, accounts for some 90 % of total national electricity generation and demand, of which by 2011 imports accounted for 77% of the total (Figure 2.1). The increased availability of imports from Uzbekistan has been the main enabling factor in this recent growth, since over this same 5-year period only one new one new generating project has been completed (the 113 MW diesel project at Tarakhil, Kabul). Demand is highly constrained not just by lack of supply, but is suppressed by both the national security problem and the poor reliability of the existing networks.

[8] It is expected that 42MW Salma hydro project will commissioned later this year.

Figure 2.1: Generation and imports, NEPS 2006-2011



	2006	2007	2008	2009	2010	2011
hydro	499	605	528	703	726	599
thermal	124	137	147	48	45	29
imports	432	609	752	1155	1533	2136

Source: Afghanistan Energy Information Centre

12. Nevertheless peak load in in Kabul has grown steadily from 121 MW in 2006 to 341 MW in January 2012, and is expected to continue to rise as Kabul expands its city boundaries as proposed in the July 2011 Kabul Master Plan.[9] An indication of the extent of expansion envisaged in the Master Plan, including provision for another two substations, is shown in the conceptual drawing taken from the report (Figure 2.2).

13. Significant captive plant load (typically comprising diesel gensets ranging between 5 kW and 1,500 kW) in Kabul is dependent on expensive diesel fuel. This demand could be transferred to grid supplies if reliability and quality of supply improved. Based on similar experience in other countries, the aggregate capacity of captive plant will be at least as much as the existing demands in the city and often presents an opportunity for the utility for co-operation in handling peaks when supply is limited. Many countries require captive plant operators to be properly registered as legitimate private power plant operators thus providing a data base that can be used for both planning and as a source of emergency power when required.

14. DABS's statistics show the total number of consumers has grown from about 200,000 in 2003 to 800,000 in 2010. Estimates of the electrification rate vary greatly, running from six to 30%. Similarly, estimates of T&D losses vary widely, making sector planning difficult.[10]

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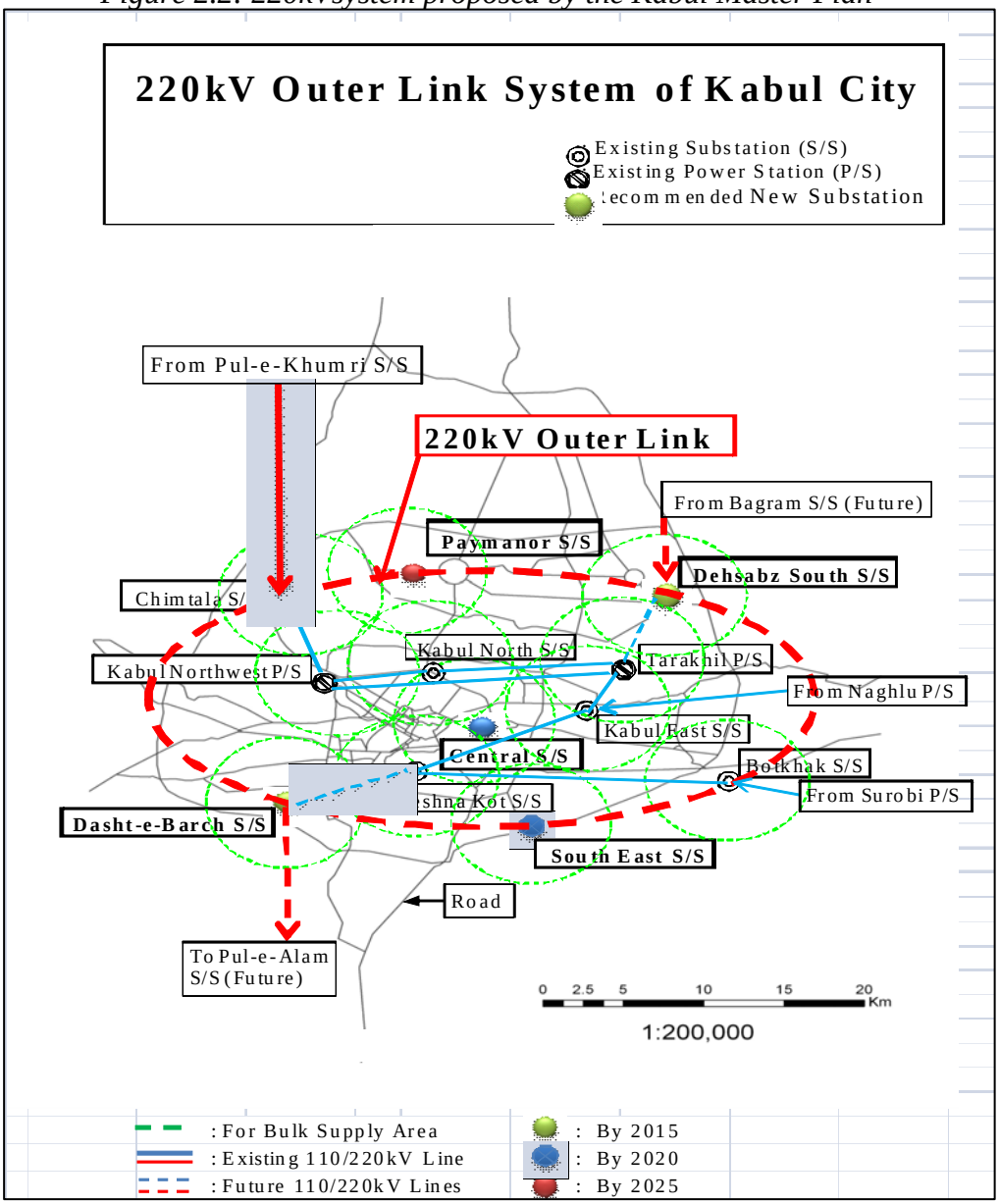
9 See Draft Kabul City Master Plan – June 2011: Technical Cooperation Project for Promotion of Kabul Metropolitan Area Development - RECS International Inc.Yachiyo Engineering Co., Ltd

10 Detailed sales data have not been sighted thus far. Aggregate estimates of T&D losses are in the range of 30 to 40%. Load forecasts will receive particular attention in the Master Plan update currently underway.

Figure 2.2: 220kVsystem proposed by the Kabul Master Plan



15. Load forecasts are correspondingly uncertain and are under study in an ongoing ADB-financed project to update the Power Master Plan. What is certain is that under the supply constrained conditions that are expected for prevail for many years, the potential 100-200 MW additional supply from the proposed MJAM coal generating plant can easily be absorbed in the Kabul area provided the necessary transmission can be put in place.

2.2 Generating projects

16. The generating projects connected to NEPS system are shown in Table 2.1. The hydro projects are quite old, and in generally poor condition.[11] The USAID-funded 113 MW Tarakhil diesel project in Kabul consists of 18 medium-speed diesel engines, each of approximately 6.3 MW, and was completed in May 2010. However, both for reasons of cost and of reported fuel shortages, in 2011 this project generated just 28.5 GWh, corresponding to an annual load factor of 3%.

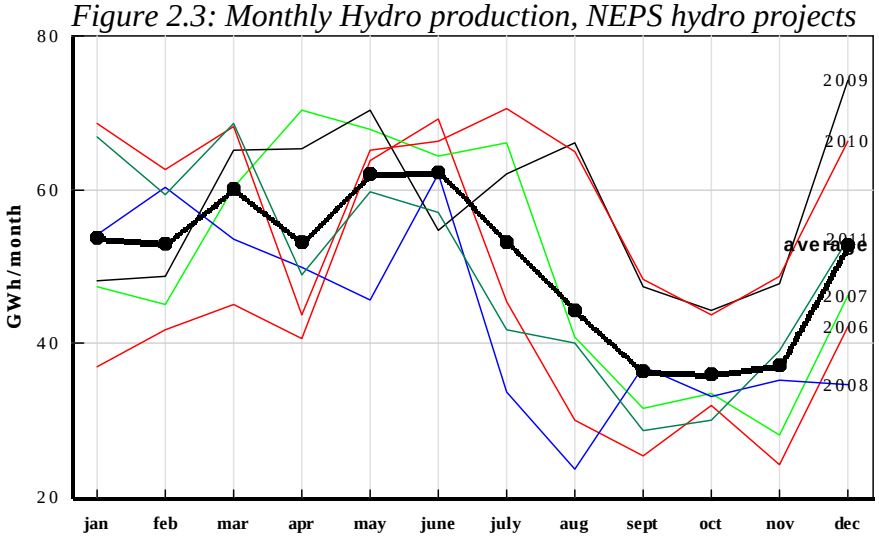
Table 2.1: Generating projects connected to the NEPS system

		startup date	installed capacity	operating capacity	2011 generation
			MW	MW	GWh
Darunta 1,2	Hydro		11.5	9.8	47.0
Mahipar 1,2,3	Hydro	1967	66	36	110.8
Naghlu 1,2,3,4 (1)	Hydro	1967	100	38	237.5
Pul-e-Khumri	Hydro	1964	14		2.4
Surobi 1,2	Hydro	1957	22	22	171.0
NW Kabul GT Unit 3,4	Thermal		45	45	0.1
Tarakhil	Diesel Gensets	2010	113	113	28.5
Total			400.2	270.5	595.0

(1) Naghlu is currently being rehabilitated under a World Bank loan but is not expected to be able to generate at full capacity until all units are brought back into service post rehabilitation.

17. Hydro production is strongly seasonal, which needs to be considered in generation and transmission planning. Figure 2.3 shows the monthly production of the existing NEPS hydro projects.

Figure 2.3: Monthly Hydro production, NEPS hydro projects



Source: Afghanistan Energy Information Center

[11] There another twelve hydro plants in the country, but aside from the Kajaki plant feeding Helmand (33 MW-1975) these are small units supplying local communities. The contribution of hydropower from these smaller projects is however quite low due to lack of water and the need for rehabilitation.

2.3 Import arrangements

18. Imports into the NEPS are governed by three PPAs:[12]

- **Tajikistan:** Agreement #30/6-BT-MEW on energy supply between Barki Tajik (Tajikistan) and the Ministry of Energy and Water (Islamic Republic of Afghanistan), dated 1382/2003; 20 year Power Purchase and Sale Agreement between Barki Tajik (Tajikistan) and DABM, dated 1387/2008 for import of up to 300MW. The current price is 2.8 UScents.
- **Uzbekistan:** An agreement has been signed for power import of up to 120 MW for 2010 over the 2 x220 kV transmission line. Protocol of the negotiations between the Ministry of Energy and Water (Islamic Republic of Afghanistan) and Uzbekenergo (Uzbekistan) on the supply of up to 300 MW, dated 2007. The current price is 7.5UScents/kWh. This has increased significantly since the 2004 Master Plan, at which time the cost of energy was assumed at 2 UScents/kWh.
- **Turkmenistan:** Amendment No. 6 to Contract No. KEN-02/03 between the Ministry of Power Engineering and Industry (Turkmenistan) and the Ministry of Energy and Water (Islamic Republic of Afghanistan) on delivery of electrical energy in direction of Imamnazar - Andkhoy, dated 2002.

2.4 Power System Planning Studies

19. The most recent comprehensive power system planning studies for the Afghan NEPS, including interconnections with the CAS bordering republics (Turkmenistan, Uzbekistan, Tajikistan), were completed in 2004 by Maunsell (ADB) and by Norplan (IDA). Other planning studies mainly relating to the Sheberghan gas-powered development and to the NEPS/SEPS 220 kV interconnections have been prepared by Tetra Tech consultants to USAID over the last 2-3 years. The most recent of these studies for the NEPS/SEPS systems, completed in February 2012, propose a number of generation and transmission measures to facilitate the interconnection.

20. The 2004 Maunsell study examined 220 kV and 500 kV alternatives to cater for power transfer of about 120 MW from Tajikistan using the 220 kV line from Pul-e-Khumri to Kabul that was then under construction. Their study confirmed the decision to build the 220 kV double circuit line (surge impedance loading (SIL) 180 MVA, thermal rating 400 MVA) and recommended that the other main interconnecting lines be built for 220 kV operation. It was recognised that actual 220 kV line ratings would be limited to SIL ratings for long uncompensated lines. However it was also assumed that in addition to the then-proposed 150 MW gas fired development at Sheberghan, there would be another 600 MW provided from the hydro developments near Kabul by 2018. This would also enable injection of reactive power at intermediate substations

[12] In addition there is a PPA with Iran: Extension No. 1 (dated 1388/2010) to the original agreement (dated 1381/2003) for Construction of Transmission Line and Electricity Energy Purchase between Ministry of Energy & Water (Islamic Republic of Afghanistan) and Ministry of Energy (Islamic Republic of Iran), but this covers imports into Heart, which is not connected to the NEPS system (for the foreseeable future).

along the nearly 600km line route from the CAS countries to Kabul to the 220kV lines to operate nearer their thermal limits.

21. The 2004 planning study by Norconsult is the basis for MEW's 2007 Power Sector Master Plan. The report recommended a number of investments in rehabilitation and reinforcement of the existing generation and transmission facilities. In 2007 Siemens/PTI (USAID) performed power system modelling studies on the above system using PSS/E to determine the transit capability and technical constraints of the proposed transmission systems. However the load flow study by Siemens/PTI assumed that the three power sources from Turkmenistan, Uzbekistan and Tajikistan were not synchronised in the Afghanistan grid.[13] The Master Plan update currently being prepared by Fichtner (funded by ADB) will no doubt take into account generation, transmission, and distribution proposals by various agencies to ensure that transmission expansion in particular is properly co-ordinated.

Power Sector Investment Programs

22. The MEW Power Sector Strategy (May 28th 2007) provides an overview of the prevailing situation including plans for rehabilitation, reinforcement and expansion (a large part of which is to reinstate lines and substations that were destroyed in recent conflicts).

23. This Strategy sets out an indication of investment requirements from 2007-15 (about US $120m). A detailed assessment of short term, medium term and longer term investments for the Kabul MV system are given in the 2007 USAID-Siemens/PTI reports. Although investment cost data are provided, it is not supported with details and often conflicts with information from other sources.

24. Funding for the various projects comes from a variety of sources including: IDA, ADB, KfW/EU, USAID, ARTF (Afghanistan Reconstruction Trust Fund), India and China. The ADB is currently the largest official donor to the sector, and has committed some $570m in four tranches, mainly for NEPS power projects from 2008-2013. This is part of an estimated $4.2 billion investment in the sector of which at least one billion is shown to be already committed.

25. A comprehensive inventory of transmission and substation proposals is available on the website of the Afghanistan Energy Information Center (AEIC). Details of individual projects are also summarised in past ICE papers.[14] A review reveals many conflicting proposals by various donors acting independently, indicating a need for DABS/MEW to take a lead role to prioritise and coordinate their proposals.

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13 There is already an extensive 500kV network interconnecting the former USSR republics which enabled parallel operation of the three systems in the past.

14 See ICE (Inter-Ministerial Commission for Energy) WB Dropbox Power Folder. Comprehensive investment summaries are prepared by ICE for every quarterly meeting. Effective May 2012 this group was disbanded, when USAID funding was discontinued.

Ongoing Studies

26. ADB in November 2010 approved a $1.5 million Technical Assistance (TA) to update the Power Sector Master Plan for Afghanistan, and the consultant (Fichtner) has commenced work.[15] The Ministry of Energy and Water (MEW) is the executing agency. This TA will provide an overview of existing generation and transmission systems; identify major potential load centres throughout the country and forecast their growth levels for the next twenty year period; and produce a plan to develop generation supply options, through both indigenous and foreign sources, and the transmission network, to connect generation facilities to these load centres. The Master Plan update will investigate domestic energy sources including coal, gas, hydro, and wind, and will examine the options for electricity trade with neighbouring countries. The TA will also present an economic analysis and financial projections for the proposed development plan. The work will be completed by the end of 2012.

27. ADB is separately funding a regional power Master Plan for the Central Asian States (CAS) and Afghanistan, for which Fichtner is the also the consultant. This will examine the electricity trade options including synchronization and related technical issues, and is expected to be completed in 2012. ADB has also recently approved a $1.5 million project for preparatory technical assistance to study options related to power trade between Afghanistan and Turkmenistan.

28. Starting in July 2012, an ESMAP funded study will examine more closely the distributional impacts of the various import and transmission expansion alternatives. The study will analyse the implications and trade-offs of making generation and transmission decisions in the face of extreme uncertainty and conflicting objectives of economic efficiency, energy security, and environmental sustainability.

[15] To date, only the inception report is available.

3. Evaluation of Future Supply Options

3.1 Introduction

29. The 400 MW coal-based power station proposed as part of the MJAM copper project would provide for some 100-200 MW of power for the NEPS system. This would provide the Kabul region with a significant source of power, and significantly changes the medium term generation capacity expansion plan. In this section we review the other generation options for NEPS, and assess how their costs would compare to the likely cost of the MJAM project.

Renewable energy

30. Significant contributions of grid-connected renewable energy generation to NEPS are unlikely, though small hydro, solar and (perhaps wind) may have significance for remote off-grid schemes: several such projects are at various stages of development.[16] However, these are too small to have any influence on transmission system development or capacity expansion options.

Cost estimates

31. An important question in evaluating generation options is the extent to which capital cost estimates in the international experience need adjustment to account for the special situation encountered in Afghanistan. Even in the absence of security considerations, construction costs in a land-locked country distant from ports will impose additional logistics costs.

32. For example, the 2004 Norconsult study estimated CCGT capital costs project at $124 million for a 100 MW project, or $1,200/kW; when adjusted to current price levels (using the MUV index), $1,392/kW.[17] This may be compared with the 2011 SNC-Lavalin estimate of capital costs for CCGT of various sizes in their recent Master Plan for Pakistan, shown in Table 3.1. CCGTs are subject to significant scale economies, and 100MW would be regarded in international practice as quite small: $1,400/kW is therefore consistent with the costs of Table 3.1, but does *not* appear to include a significant Afghanistan-specific cost adjustment.[18]

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16 Information regarding the potential for solar and wind resources can be found on the Afghanistan Resource Maps and Toolkit website, which contains high resolution maps and data products for Afghanistan http://www.nrel.gov/international/ra_afghanistan.html

17 The MUV (Manufacture Unit Value) index is published on the World Bank website, and is widely used to update cost estimates for power equipment sourced in the OECD countries. The 2004 value is 98.67, the 2011 value is 114.46.

18 This cost was used even in Norconsult's "unlimited gas" scenario that added 7 50MW units over a 12 year period.

Table 3.1: Capital costs for CCGT

Installed capacity, Adjusted to site conditions	Capital cost (economic)
MW	$/kW
215	1,100
458	911
707	867

Source: SNC-Lavelin, *Pakistan: National Power System Expansion Plan,* 2010-2030, *Final report, Annexure A2: Generation Planning,*

33. A more recent evaluation of the Sheberghan project[19] documents that the substantial incremental security and logistics costs add 60% to general international price levels for power generation equipment: it estimates international cost for a 200 MW size CCGT at $1,000/kW, when adjusted by a 1.6 multiplier equal to $1,600/kW.

34. What is also clear is that many of the estimates of supply costs for new generation projects found in the various energy planning documents are quite unrealistic. For example the 2007 Energy Sector Strategy document shows generation costs as shown in Table 3.2: only that for diesel can be regarded as realistic.

Table 3.2: Generation costs

	UScents/kWh
Hydro	2.29
Imports	2.62
Diesel	29.53
Gas	2.8-3.5
Coal	Not available

Source: 2007 Energy Strategy *op.cit*., Table 4.

3.2 Hydro

35. The 2004 Norconsult Master Plan identified 15 potential hydro sites with an aggregate capacity of 1,500 MW, mostly located Northeast of Kabul. In particular Norconsult recommended that the Bagdara and Surobi 2 plants be built as soon as the riparian rights can be negotiated with Pakistan. Norconsult proposed the first two units (2×70 MW) of Bagdara could be commissioned within five years, with unit 3 (70 MW) and unit 4 (70 MW) built 12 months and 24 months later.[20] Such a development would suggest the duplicate 220kV line would be built on the eastern side of the existing 220kV connection between Pul-e-Khumri and Kabul. Norconsult also recommended a first 60 MW unit at Surobi–II, followed by unit 2 (60 MW) and unit 3 (60 MW) 12 months and 24 months later.

[19] Advanced Engineering Associates International (AEAI): *Sheberghan Gas Field Development Project*: *Gas/Power and Related Infrastructure Assessment*, Report to USAID, April 2011.

[20] The Fichtner Inception Report list of hydropower candidates shows Surobi as 200MW (rather than 3 x 60MW), and Bagdara at 210MW (rather than 280MW)

36. The Norconsult hydro project cost estimates also require updating, as shown in Table 3.3. Assuming fixed O&M costs at 2% of capital cost, and 50 year economic lives, (economic) hydro production costs compute to 9.2 UScents/kWh for Bagdara, and 12.8 UScents for Surobi.

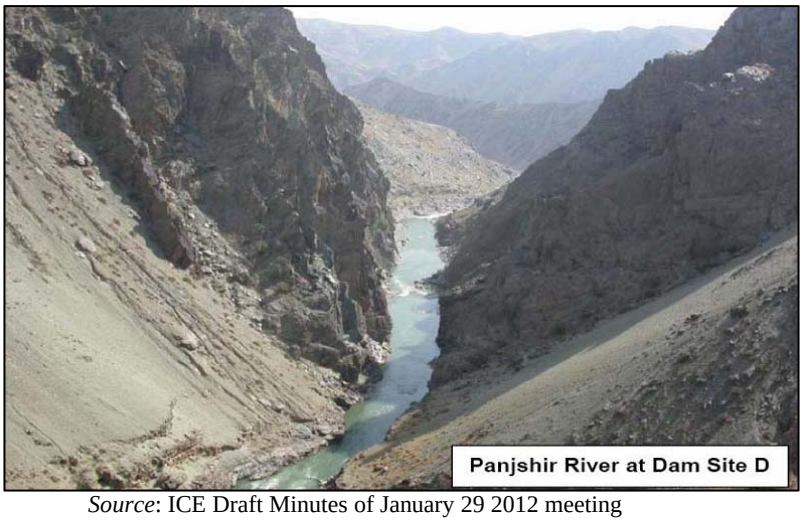
Table 3.3: Hydro project costs

				Unit capital cost		
	Capital cost	Installed capacity	Average annual energy production	2004 price	current prices (MUV adjusted)	Average energy cost
	$USm	MW	GWh	$/kW	$/kW	USc/kWh
Bagdara	620	280	1,177	2,214	2,568	9.2
Surobi-II	465	180	630	2,583	2,997	12.8

Source: Norconsult, 2004, *op.cit*

37. The basis for including these projects in the 2004 Master Plan "least cost dispatch" scenario is unclear. Neither project has a modern feasibility study (whose immediate completion was recommended by the Master Plan). The main rationale for their inclusion is that these were the only projects (together with the extension of the Kajaki project) that were seen as practical to implement within the next 10 years (a somewhat surprising rationale given the absence of modern FS).[21] Moreover, the appearance of the Bagdara dam site (Figure 3.1) is deceptive: notwithstanding the steep gorge at the site itself, according the Master Plan this project would inundate agricultural land and need to relocate significant numbers of people, for which extensive environmental and social management planning would be needed.

Figure 3.1: The Bagdara dam site



Source: ICE Draft Minutes of January 29 2012 meeting

[21] Norconsult 2006 Master Plan, Chapter 6 (Candidate Projects for Development)

3.3 Coal

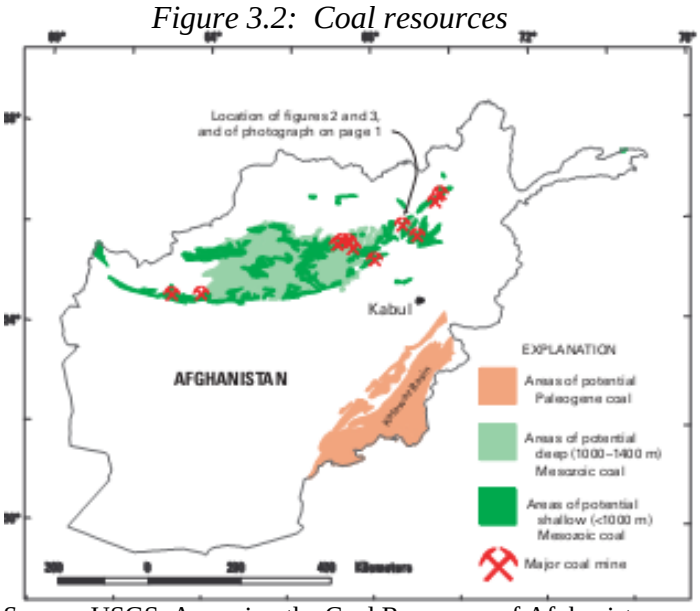
The coal resource

38. There are significant coal deposits in Afghanistan many of which lie north-west of Kabul (Figure 3.2). In particular this includes the Ishpushta and Qaleech field in Bamyan province which, as noted, is currently being investigated by MJAM (under the terms of the Aynak copper mine contract) as the potential site of a 400MW coal fired power station.

39. MJAM's 70 km^2 concession area is about 18 km by 4 km. The stated aim of MJAM's drilling program is to identify a resource that can supply 1.5 million tons of coal/year over a 30 year period.[22] Drilling work began in 2009 and by 2011 MJAM had completed 18 boreholes with total drilling length of 5,000 meters. In the western part of the concession, MJAM predict 78 million tonnes of coal reserves with another 12 million tonnes in the east.

40. MJAM's investigation programme has been frustrated by several terrorist incidents including gunfights, attacks and mines. The access road from Doshi to Bamyan is in a poor state of repair and was cut off for at least a year. In the coming months however, subject to increased security support by the Afghan Government and the completion of the feasibility studies, MJAM plans to develop the mine, power station and transmission line for construction start in 2013..

Figure 3.2: Coal resources



Source: USGS, Assessing the Coal Resources of Afghanistan

[22] A 400MW coal fired plant operating at 70% load factor would be expected to require about 3,000 tonnes of coal per day.

Cost of the coal project

41. Neither the capital cost nor operating cost of the MJAM coal project is known. The production costs of coal mining are also unknown. The Norconsult report assumed that indeed FGD be required using a limestone process.[23]

42. The basis for the Norconsult estimates in the 2004 Master Plan are similarly unknown. The "unlimited coal scenario" envisaged the development of a 7x50 MW coal project at Shabakshak, with coal priced at $30/ton, and with capital costs estimated at $100 million for each 50 MW unit ($2,000/kW). 50 MW units are certainly quite small in current practice, which may account for the high capital cost. However, SNC-Lavalin's 2011 estimate for 600 MW coal units in Pakistan was $1,850/kW. Based on $100/ton (for imported coal), the coal generation cost (at 80% PLF) was estimated at 10.9 UScents/kWh. This seems on the high side, given reported costs in other Asian countries that are in the range of $1,200-1,500/kW.

43. It seems likely that MJAM will use Chinese manufactured plant, for which the closest project about which we have information is the 300 MW phase I project at Puttalam, Sri Lanka, financed by China EXIM Bank, and built by a Chinese contractor.[24] The reported (financial) cost for this project is US$455million, or $1,517/kW.

44. Under the particular circumstances of the MJAM deal, the economic cost of coal-fired generation can be taken simply as the expected tariff. Trying to differentiate between "financial" and "economic cost" following conventional World Bank practice is simply not possible, particularly in view of the up-front concession payments envisaged by the MJAM deal, some part of which represents the resource rent associated with the copper ore, and (presumably) some part representing the resource rent on the coal resource (the bulk of the power being needed by MJAM itself).[25]

45. The cost of the power to DABS, or even the principles by which the tariff is to be established, are unknown. Much less do we know how MJAM will finance the

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23 The Norconsult report states "it is assumed that the coal contains 2-3% sulphur", but the basis for this statement is unknown.

24 World Bank, *Sri Lanka Energy Sector Infrastructure Assessment*, 2010. Such Chinese construction projects typically bring their own construction workforce, so employment opportunities for the local economy (other than providing security) may well be quite small.

Indeed, how the security is to be provided during construction will be a critical factor in any decision to proceed. It is not unknown in international practice for construction companies to hire their own armed security forces (as for example during the construction of the Bumbuna hydro project in Sierra Leone, where the Italian construction consortium engaged a private South African force to (successfully) protect the dam site during the Sierra Leone Civil War in 1992-2002)

25 The MJAM consortium from China offered a premium of $808 million payable in three tranches, in addition to the taxes, royalties and other fees enshrined in the mining law and the contract. The first tranche of the premium, $80.8 million, was paid to the government in September 2008; the next tranche of $161.6 million will be paid upon the approval of the feasibility study; and the final tranche of $565.6 million will paid upon the commencement of commercial production

power project.[26] Whether actual coal production costs are 10$/ton, 30$/ton or $50/ton is also hard to state at this time.

46. Table 3.4 shows the result of a tariff calculation as a function of the financial capital cost ($/kW) and the coal production cost ($/ton). The assumptions are

- 4-year construction period, IDC capitalised
- heat rate 9,100 BTU/kWh, heat value of coal 6,000 BTU/Kg
- 30% equity, 20% return on equity
- 70% debt, 4-year grace, 15 year repayment, 8% interest
- 80% annual plant load factor
- Fixed O&M 30$/kW/year
- No income or resource taxes and royalties

Table 3.4: Required coal project tariff, UScents/kWh

	$/kW									
$/ton	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100
10	3.7	3.9	4.1	4.3	4.5	4.7	4.9	5.1	5.3	5.6
20	4.0	4.3	4.5	4.7	4.9	5.1	5.3	5.5	5.7	5.9
30	4.4	4.6	4.8	5.1	5.3	5.5	5.7	5.9	6.1	6.3
40	4.8	5.0	5.2	5.4	5.6	5.9	6.1	6.3	6.5	6.7
50	5.2	5.4	5.6	5.8	6.0	6.2	6.5	6.7	6.9	7.1
60	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.3	7.5
70	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	**7.6**	7.8
80	6.3	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2
90	6.7	6.9	7.1	7.4	7.6	7.8	8.0	8.2	8.4	8.6
100	7.1	7.3	7.5	7.7	7.9	8.2	8.4	8.6	8.8	9.0

Note: the shaded area denotes combinations of capital cost and coal price that result in prices below 7.6 UScents/kWh

47. Assuming a baseline cost of $1,250/kW, and applying the 1.6 locational adjustment, we take the capital cost at $2,000/kW. Assuming further that the actual production cost (i.e. exclusive of resource rents) is 70$/ton, the baseline power cost is UScents 7.6/kWh. Of course, in the event such a coal project were developed by the mining operator, the coal price is an internal transfer price within the MJAM operation. Therefore, even though the understanding is that power will be sold to DABS "at cost",[27] it will be particularly hard to verify what are the actual costs of the coal production (by contrast, verification of the cost of power generation itself is easier). Capacity building at MoM should include monitoring of mining and contract compliance

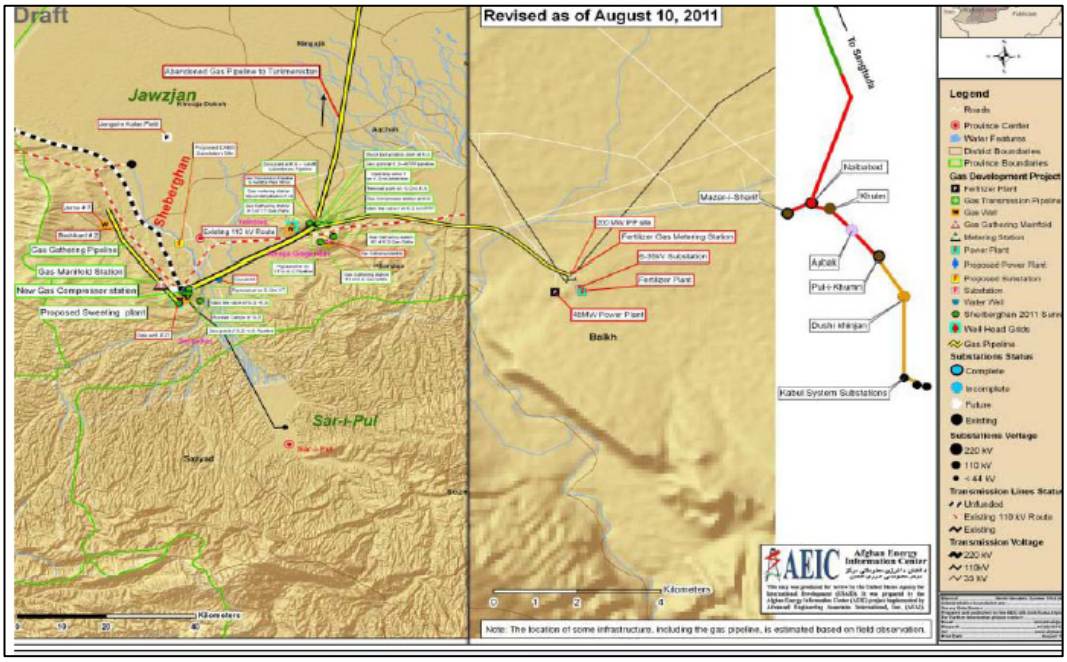
[26] For example, what is MJAM's WACC is unknown, or even whether it has access to China EXIM bank finance. Based on what is known from the Sri Lanka project, EXIM Bank finance "development loans" have 5 year grace period and 15 year repayment period and 2% interest rate; "suppliers credits" have 10 year repayment and 8% interest. These are considerably less favourable than JBIC loans, for example, with typical 10 year grace periods, 30 year repayment period and 1% interest rate.

[27] World Bank, Mining Sector Chapter, *Afghan Growth Corridor Study*, Draft, October 2011

3.4 Gas

48. Although the Sheberghan gas resource has been thoroughly investigated based on Soviet data, guarantee and financing agencies have been reluctant to proceed with the development without further drilling to prove the resource. Notably the gas is considered to be "sour" i.e., contaminated by corrosive impurities that will have to be removed before it can be used in modern combustion machines.[28] The 2005 Maunsell study for USAID recommended reciprocating gas engines with waste heat recovery be used for the power plant, with gas treatment consisting of H_2S removal using amine scrubbing, H_2O removal using glycol dehydration, solids filtration and pre-heating. The consultants considered four power plant technology options including reciprocating gas engines, combined cycle gas engines, open cycle gas turbines and combined cycle gas turbines.

Figure 3.3: Sheberghan and Mazar-e-Sharif Gas and related infrastructure



49. In the original 2004 Norconsult study it was assumed that the resource was sufficient for a 2x50 MW project. The 2006 Maunsell report recommended 5x20 MW reciprocating gas engines.[29] The more recent report by AEAI assumes CCGT as the most likely, but sufficient for 2x100 MW.[30]

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28 The principal impurities to be removed from natural gas in the Sheberghan fields are hydrogen sulphide (H_2S) and water (H_2O). Suitable processes for removal of H_2S include amine scrubbing, incineration, sulphur recovery, re-injection, biological and iron redox. Water vapour removal by glycol dehydration, solid-desiccant dehydration or Joule-Thompson valve technology were identified as the most suitable processes for the Sheberghan gas supply.

29 http://www.afghaneic.org/library/feasibility%20studies/Appendicess%20A-S.pdf

30 Advanced Engineering Associates International (AEAI): *Sheberghan Gas Field Development Project*: *Gas/Power and Related Infrastructure Assessment*, Report to USAID, April 2011.

50. The latest estimates by AEAI, presented at the May 27, 2012 meeting of the ICE, assumes a gas price of $90-$100/MCM ($2.55-2.83/mmBTU) would be needed to stimulate the necessary gas production, resulting in a power generation cost of around 6 UScents/kWh.[31] Gas pricing policy in Afghanistan is at an early stage of discussion, and given the uncertainty about the resource, estimating an appropriate depletion premium is speculative.[32] Even the value of the gas for power generation measured by the next best domestic generation alternative, likely to be coal, is difficult. What does seem reasonable, however, is that for the purposes of evaluating the economics of the Sheberghan gas project one bases the economic value of gas on the current Uzbek gas export price ($8.2/mmBTU), suitably adjusted for transportation differentials.

51. The question of implementation approach is still under discussion, since the investors in the Sheberghan Gas to Power Project have suggested a modular power plant, possibly in 50 MW blocks, allowing generation capacity to come online to serve local demand initially, and to be transmitted as transmission line projects were completed. It was noted that "a modular approach also allows a more safe and sustainable investment." While this may well be so, 50MW increments in a CCGT will incur significant scale diseconomies. This will be one of the issues in the updated Fichtner Master Plan update: perhaps use of small reciprocating gas engines is less subject to scale diseconomies.

52. DABS is reported as being willing to replace the existing power imports from Turkmenistan with the Sheberghan IPP power supply for the region, provided that the IPP power plant could supply the electricity for the same price. Currently, the PPA with Turkmenistan sets the price at 2.8 cents US/kWh, so generation costs in the range of 6-8 UScents/kWh will not meet this requirement in the short term, though gas generation may be competitive at the *Uzbekistan* import price of 7.5UScents/kWh.

3.5 Oil

53. Afghanistan appears to have significant oil resources that are currently being explored by Chinese developers.[33] In particular a Chinese contractor expects to commence producing in the Amu Darya field contract area adjacent to the Sheberghan site by the end of 2012. Three prospective blocks, the Kashkari, Bazarkhami and Zamarudsay, have already been proven with 24 wells drilled by the Soviets, and have aggregate reserves of about 50 million bbls. Expected production is 15-20,000 bbl/day, and additional seismic exploration is required of the contractor. However, further diesel-based projects like Tarakhil would unlikely be recommended by the Master Plan update.

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31 The critical uncertainty is the capital investment required to develop the Sheberghan gas field to the point at which it can supply enough gas for a 200MW CCGT over a 30 year lifetime. This was estimated by AEAI at US$124million, including $59.5million for a gas sweetening and conditioning plant, plus the pipeline infrastructure to deliver the gas to the IPP site.

32 See e.g. World Bank, *Considerations for Gas Pricing Principles in Afghanistan*, July 2005.

33 The Canadians are also undertaking seismic work, but are not expected to be developers in the foreseeable future.

3.7 Imports

54. The extent to which Afghanistan can continue to rely on imports is one of the main uncertainties facing the power sector. A 2004 World Bank report[34] indicates that although the export potential of the Central Asian States countries is significant, it is potentially constrained by political, economic and technical issues.

Export Potential of the CAS

55. The Central Asian States are endowed with considerable energy related natural resources many of which were developed to supply the FSU. The Kyrgyz Republic and Tajikistan have abundant hydropower potential but negligible amounts of commercially exploitable fossil fuels. In contrast, Kazakhstan has significant reserves of oil, gas and coal; Uzbekistan has substantial gas reserves as well as some oil and coal; and Turkmenistan also has substantial gas reserves together with some oil.

56. While the report indicated that the costs of CAS generation (in 2002) were remarkably low, it would be prudent to expect that this situation is unlikely to prevail in a competitive market. In this respect Afghanistan, Pakistan, India, Russia and China are all potential markets for energy produced in Central Asia. Pakistan and Iran have the added attraction of experiencing their peak electricity demand in the summer when the largest potential electricity surpluses exist in Central Asia. Moreover, annual domestic demand in the CAS is growing, and beyond 2020 any new generation development for export to Pakistan and Iran in particular will need to be justified in a more competitive environment. Table 3.5 summarises the relative sizes (and influence in terms of synchronising power) of the generation capacities each of Afghanistan's neighbours.

Table 3.5: CAS power systems, 2008

2008 Data	Turkmenistan	Uzbekistan	Tajikistan	Kyrgyzstan	Iran	Pakistan
Generation, TWh	14	47	16	12	201	88
Capacity,MW	2,852	11,580	4,426	3,640	52,965	20,000
Thermal	99.6%	85.2%	9%	20%	85%	65%
Hydro	.04%	14.8%	91%	80%	14.5%	32%

Source: Renewable Energy Intelligence Site http://www.energici.com/

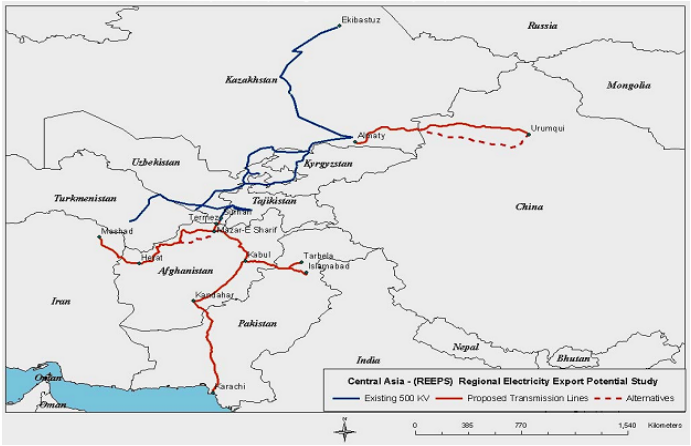
57. While its domestic import requirements are not likely to be very significant in terms of the export surpluses available, there is an opportunity for Afghanistan to both increase its imports and to profit from wheeling power mainly to Pakistan (and possibly Iran) by building transit lines in as indicated in Figure 3.4. This opportunity would get around the problems of having to increase imports on existing 220kV circuits that are limited in capability to transfer large amounts of power and constrained in operations by the complexity of having to manage asynchronous supplies to meet local demand.

58. Importantly it should be noted that the most economic design of transmission for such trans-Afghan links would probably utilize HVDC to take advantages of the

[34] See World Bank, *Central Asia Regional Electricity Export Potential Study*, 2004.

lower costs of long HVDC lines and to tackle the problem of connecting asynchronous systems.

Figure 3.4: Regional Electricity Export Potential Study

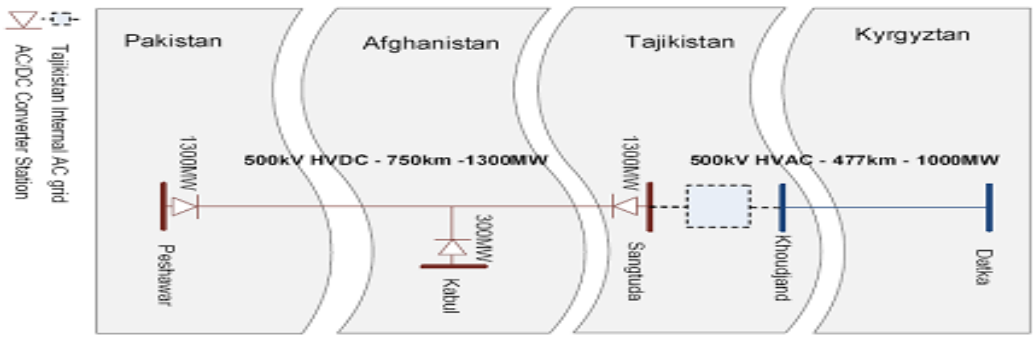


Source: World Bank, *Central Asia Regional Electricity Export Study*, 2004.

HVDC Import Options

59. As noted, the first proposal for delivering power to Afghanistan from the CAS by HVDC is the "CASA-1000" project (see Figure 3.5). This involves the export of electricity (hydro surplus) from Kyrgyzstan and Tajikistan to Pakistan and Kabul by means of a 500kV AC connection between Kyrgyzstan and Tajikistan, and a 750km HVDC connection between Tajikistan and Peshawar, with a spur to Kabul. In additional to the terminals in Tajikistan (Sangtuda) and Pakistan (Peshawar), it provides for one intermediate HVDC/AC converter terminal just north of Kabul airport (300MW capacity), probably with 220kV links to Chimtala and the Tarakhil power station. The intermediate terminal would provide a significant stabilizing contribution to the NEPS at Kabul.[35] However, the HVDC CASA power transit line should not really be considered as an integral part of the NEPS.

Figure 3.5: The CASA-1000 proposal



Source: CASA-1000, *op,cit*., Figure E-1

35 The extent to which the injection of power at Kabul will stabilise the NEPS system was analysed in the earlier PSS/E study by Siemens/PTI.

Box 1: HVDC Transmission

High Voltage Direct Current systems are widely used in various forms together with a conventional HVAC system to achieve a number of economic and technical benefits. In their basic form HVDC facilities can effect interconnection by installing an AC-DC rectifier and the DC-AC inverter within a single building. These facilities typically cost $200/kVA (compared with about $20/KVA if an AC transformer substation is used to connect two synchronised systems with different voltages). HVDC B/B systems are only used in rare situations when two large systems cannot be easily interconnected e.g. at the Turkey to Georgia border.

HVDC transmission construction requires only two conductors (as opposed to 6 for HVAC of equivalent load carrying capacity) and therefore can be built on much simpler tower structures for typically half the cost per km of an HVAC line with equal load carrying capacity and improved reliability. Taking into account the cost of AC-DC-AC conversion, HVDC transmission is normally the most economic method of power transit without intermediate loads over about 300km. It is typically used in many countries (Australasia, EU) to supply power to a load centre 600km or more distant.

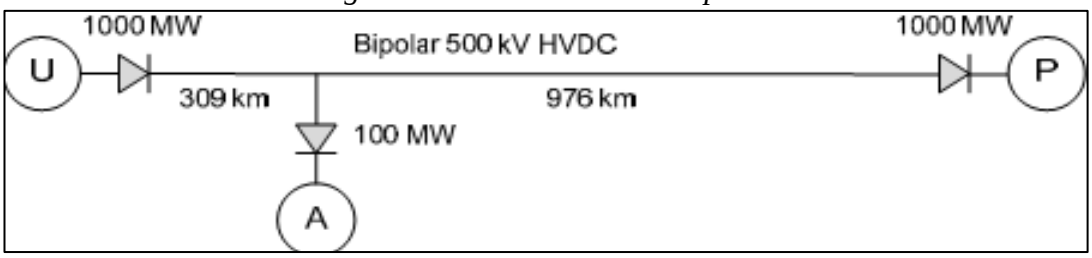
HVDC is also used in parallel with an HVAC network serving many intermediate substations en route. In this way HVDC provides bulk power from one end to the other as well as fast acting reactive power support at either end of the line as necessary for system stability. It is used in this way in India and the West Coast of the US. It appears suitable as a long term option for solving the combined problem of synchronisation along with reducing the cost and increasing the reliability of power transit operations through Afghanistan.

60. The CASA study provides angle points of the transmission alignment much of which is alongside existing routes taken by the 220 kV line. The study discusses proposals for mitigating congestion through the 3,800m Salang pass including rerouting the HVDC line through the Shibar pass (closer to the proposed HajiGak iron ore mine and the MJAM coal-fired plant at Ishpushta), undergrounding a 7 km portion of the 220 kV line, and rebuilding part of the 220 kV line on compact steel poles to provide room for the HVDC line. These options will need to be considered further during the detailed design.

61. In March 2012, a second export project was reviewed for the World Bank by SNC/Lavalin: the Uzbekistan-Afghanistan-Pakistan Energy Supply and Trade Project (UAP-EST) project.[36] This proposes a new HVDC line running from Mazar-e-Sharif to Kabul taking an alternative more direct route via Bamyan (Figure 3.6). This project differs significantly from the CASA-1000 proposal in that it will deliver year-round base load power (based on gas CCGT) rather than hydro surplus in the summer months.

[36] SNC/Lavalin, *Uzbekistan-Afghanistan-Pakistan Electricity Supply and Trade Project*. Draft Report, March 2012

Figure 3.6: The EAP-EST Proposal



Source: EAP-EST, *op.cit*., Figure 6-1.

62. Recent discussions have raised the possibility of increasing the capacity of the line to 1,300 MW and even 1,800 MW, and suggesting that HVDC be integrated into Afghanistan's transmission network (discussed further in Section 4).

63. In principle, regional electricity trade projects that would deliver 100-200 MW to NEPS near Kabul (en route to Pakistan) are attractive to Afghanistan, since these would diversity the supply mix and the transmission network, and improve the stability of the system. However, the economic and financial analyses of the present proposals (CASA-1000 and UAP) need to be further developed and extended to include a distributional analysis.[37] To be able to take an informed view of these proposals and include them in their power sector expansion plans, realistic tariff proposals based on an equitable apportionment of costs and benefits are needed by the Government of Afghanistan.

64. For these projects to benefit Afghanistan, tariffs need to be competitive with alternative sources (which in the first instance would be gas-generated power imported from Uzbekistan in Afghanistan's HVAC system, though subject to resolution of the synchronisation problems noted elsewhere). There are also questions about what capital investment would be required of DABS, and the extent to which that investment is in equitable proportion to the benefits.[38] Finally one should also note that whatever the price, they still represent imports, and therefore for sake of increasing supply diversity, need to be balanced by domestic generation projects (hydro, coal and Afghanistan's own gas).

[37] For example, the levelised CCGT generation tariff (based on Uzbekistan's border price for gas exports to its neighbours) is estimated by the UAP feasibility study at 11 UScents/kWh, plus 2.2 UScents/kWh for the interconnection. At such a price, this option is unlikely to be attractive to Afghanistan, because Afghanistan only derives 10% of the benefits, and its equitable share of the interconnection cost should therefore be significantly less than 2.2 UScents/kWh

[38] The bulk of the economic benefits are generated in Pakistan, where the opportunity cost of energy is determined by the much higher price of CCGT generation from imported LNG (13.2 UScents/kWh).

4. Transmission system expansion

4.1 Existing Transmission Plans

65. Many large investments in NEPS are apparently stalled due to the uncertain political situation, security issues and financing requirements. The major 220kV transmission projects currently under consideration by ADB and USAID are of particular interest in that they may need to be reviewed in terms of how the transmission system should develop to optimise its use for supporting the proposed corridor developments. In the meantime ADB is currently seeking consultants to identify priority projects for its Multi Financing Facility (Tranche 4) from a list prepared by DABS (Table 4.1).

Table 4.1: ADB Multi-financing Facility for Energy Tranche 4

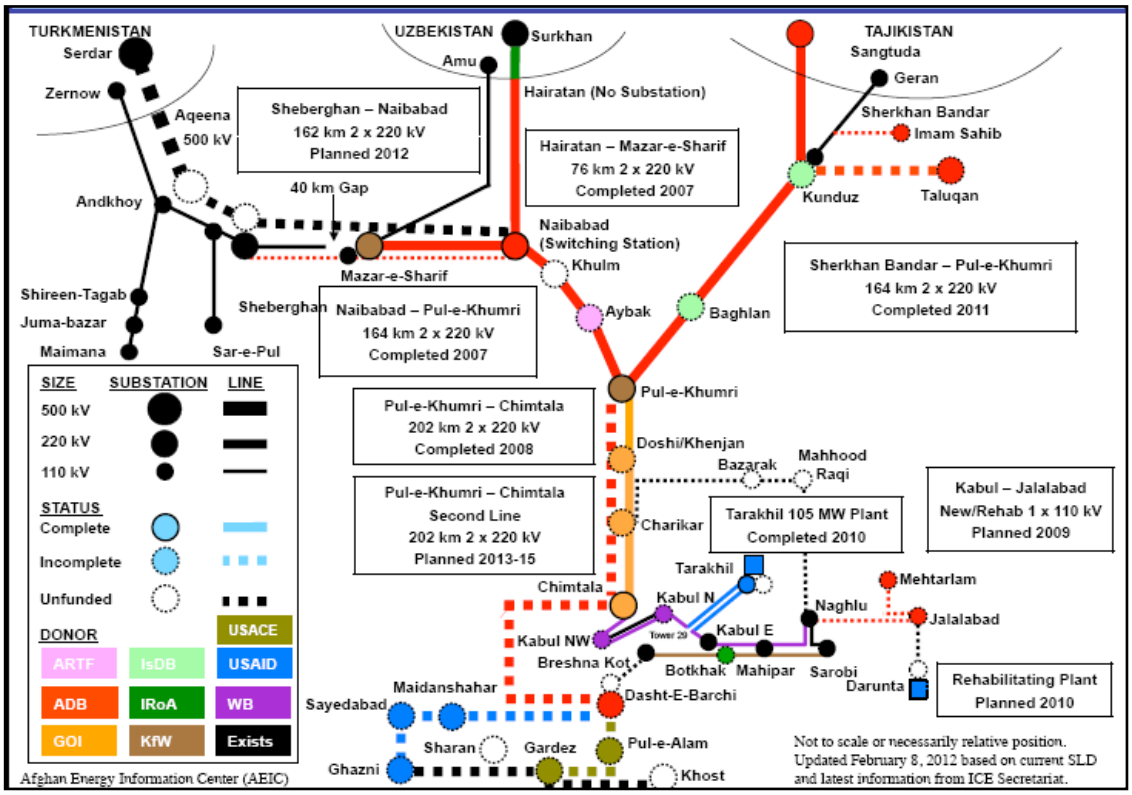
Projects under consideration by ADB consultants	$USm
Rehabilitation of Kabul New City Distribution Network	20
Kabul new City	20
Design & Construction of 2x220kV from Pul-e-Khumri to Chimtala substation	100
Design & Construction of 2x220kV from Dasht-e-Barchi SS to 3*16MVA Logar SS and MV/LV distribution	45
Rehabilitation of Sheberghan Logar and Gardez MV and LV distribution network	45
220kV Transmission line from Sheberghan to Naibabad (for Sheberghan gas-fired power plant)	75
AFG-TKM 500kV Power Transmission Interconnection	120
Total	405

66. USAID has a particular interest in three major projects that are apparently likely to proceed in the near future. These include: (i) Power Transmission Expansion and Connectivity Project (PTEC)[39]; (ii) the Kandahar-Helmand Power Project (KHPP); and (iii) the Sheberghan Gas Development Project (SGDP). The PTEC project that is designed to enable the interconnection of Kandahar with the NEPS is apparently quite well advanced in terms of planning with a route design already finalised and generation support (in the form of a solar power plant) under consideration in Kandahar.

[39] This covers a US$1.3 billion program for transmission expansion ($981 million in on-budget, pursued through a contract with DABS) to include: Improvement of South East Power System (SEPS) transmission and distribution ($176 million); Expansion of the throughput capacity of North East Power System (NEPS) ($300 million) Connection of NEPS to SEPS ($380 million); Synchronization of Afghanistan's power system to neighbouring systems, specifically Uzbekistan ($50 million);Contingency for on-budget support ($75 million as part of contract with DABS);Engineering oversight, monitoring and quality assurance ($182 million off-budget) Capacity building, technical assistance, training, and commercial operations ($128 million off-budget, pursued under the AID/Kabul OIEE Energy & Water IQC).

67. MEW's 2004 plan envisaged investment through 2020 of $776 million (discounted).[40] Over the last few years the plan has developed and incorporates a number of changes partly driven by the proposals from USAID, ADB and other donors. The various components of the current version of the recommended plan for the NEPS are expected to be financed from various sources, as indicated in 4.1.

Figure 4.1: NEPS status



68. Interconnection of the NEPS to the much larger Pakistan power systems is not possible while the NEPS is synchronised with any one of the CAS systems. Until a regional power market develops to the extent that the FSU countries re-establish synchronisation between each other and with Pakistan or Iran, the only feasible regional interconnection technology is via HVDC lines or back-to-back converter stations. Current interconnection proposals include (i) as reflected in the power import agreement with Turkmenistan, a 500 kV line from the Serdar substation (in Turkmenistan) to Andkhoy East (in Afghanistan); (ii) the CASA ±500 kV HVDC line from Tajikistan to Pakistan via a converter terminal in Kabul and (iii) the Uzbekistan to Pakistan UAP-EST HVDC project.

69. According to the ICE reports, DABS is keen to extend the 500 kV networks within Afghanistan with the intent of interconnecting with the CAS 500 kV networks. However, given current demand projections in Afghanistan, and given the synchronism problems are likely to persist for some time, a 500 kV HVAC network appears to be

[40] Based on the World Bank funded Project AFG 03170 *Power Sector Master Plan*, Norconsult 2004

neither technically appropriate nor economically viable (although it may be operated at 220 kV in the short term). This is because with low loadings and long distances 500 kV voltage conditions would be difficult to control without complex and expensive series or parallel reactive compensation equipment.

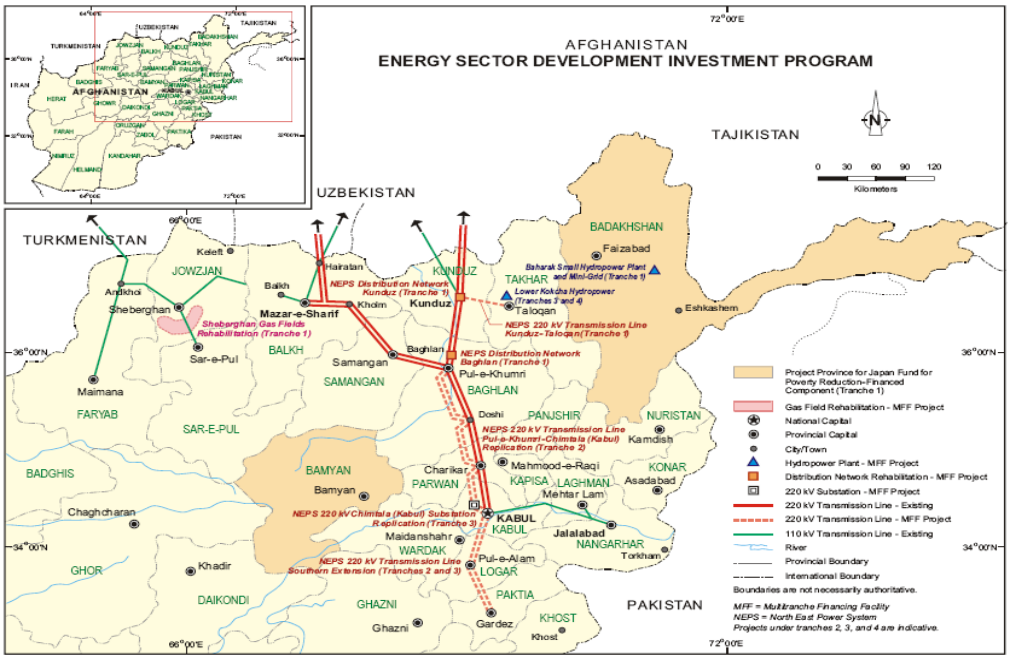
70. Under the ADB funded 2012 Master Plan there is a proposal to facilitate the interconnection of the various Afghan networks that is based on the assumption that it is unlikely that the CAS countries will resynchronise or that Afghanistan will develop its own coal and gas resources sufficient to meet its domestic growth in the next decade. The proposal recommends building four separate HVDC B/B facilities at Pul-e-Khumri, and at Jalalabad to allow Afghanistan to operate its own synchronous system independently of its neighbours. Each of the HVDC B/B facilities would be sized according to the capacity of the respective CAS country's nominated export capabilities. Aside from the dubious technical rationale for the proposal (as discussed below), it lacks any real flexibility for modification in case conditions change.

71. A pragmatic approach that offers more flexibility and less risk under changing supply conditions would be to encourage more cross border trading links (similar to the CASA 1000 scheme) taking advantage of the much lower costs of long HVDC lines. For example an export scheme from a CAS country to Iran or Karachi employing a separate HVDC line with an intermediate terminal at Kabul or Kandahar could be used as the main source of back-feeding through the 220 kV system to the smaller regional centres. It should be possible to design transit lines so that even if the export business failed to materialise the HVDC line would still play a vital part in Afghanistan's power systems operations.

72. Under the ADB Energy Sector Development Investment Program[41] transmission plans currently contemplate building a duplicate 220 kV line over the Salang pass (as shown dashed in Figure 4.2). This would be designed to increase the capacity of the existing transmission route from 300 MW to at least 600 MW. USAID is currently also investigating the possibility of increasing the capacity of the various existing 220 kV double circuit lines from Uzbekistan to Kabul. In total these interconnecting lines extend about 600 km from the supply point and are limited by the aggregate SIL to 150 MW/circuit. USAID proposes to increase the double circuit capacity of the system to about 450 MW total using series and parallel compensation en route, with the additional aim of providing for the export of up to 150 MW into to the SEPS system. Under the CASA project there is also a proposal to build a 300 MW ±500kV HVDC link over the Salang pass following a similar route to Kabul (where it would inject another 300 MW into the NEPS) and across to Pakistan.

[41] See ADB, P*roposed Multi-tranche Financing Facility and Administration of Grant from the Japan Fund for Poverty Reduction Islamic Republic of Afghanistan: Energy Sector Development Investment Program* Project Number: 42094, November 2008.

Figure 4.2: Existing Transmission development plan



73. There is a strong case for reserving the alignment following the north-south route of the existing 220 kV via the Salang Pass for the proposed ±500kV HVDC CASA line. HVDC line construction is much simpler than a conventional double circuit 220 kV line because it uses only two low profile, heavy duty conductors that are less prone to damage due to icing and wind loadings. Moreover unlike 220 kV HVAC, HVDC cannot be interconnected to loads or generation en route, so to keep costs down it should be designed take the shortest route to Kabul and thence to Pakistan. There is also a possibility (that needs to be investigated further) of suspending two HVDC cables from inside the existing tunnel roof to bypass the extreme conditions over the mountain.[42] However the feasibility of doing this may be constrained by the risks of fires due to the heavy traffic volume through the tunnel.

74. On the other hand if DABS/ADB goes ahead and simply duplicates the existing 220 kV line, such a reinforcement measure would do little to enhance security of supplies to Kabul - particularly during winter storms or owing to terrorist activity - and would not facilitate interconnection of the Ishpushta 400 MW PS/ HajiGak coal/ Bamyan town centres. Termination of multiple 220 kV transmission circuits in Kabul's northern Chimtala Substation would increase its vulnerability to bus or feeder faults (or to terrorist acts). With so many circuits emanating from the substation, a (not uncommon) bus fault event would undoubtedly cause significant problems for the

42 The drawings for the tunnel show there is in fact enough space above the tunnel to do so (see *Salang Tunnel and Snow Galleries Drawings, Norwegian Public Roads Administration, Afghanistan Ministry of Public Works*). Maintenance for this kind of cable would be minimal, perhaps once every 20 years to check the support structure. However, even well designed and maintained road tunnels have a certain fire risk (as shown in the case of the Gotthard Road Tunnel Fire in Switzerland 10 years ago).

Kabul system, even if Kabul can be islanded and supplied from Naghlu and Mahipar by the 110kV system from Kabul East.

75. Accordingly it would be preferable to find another transmission route for a 220kV north-south line terminating on the southern side of Kabul (at Dash-e-Barchi) – and thereby enable a direct supply to Aynak mine as well as providing an alternative supply point for power distribution in Kabul. As part of a future project to secure a 220kV ring around Kabul is assumed that ADB would go ahead with a 220kV connection between Chimtala and Dash-e-Barchi.[43]

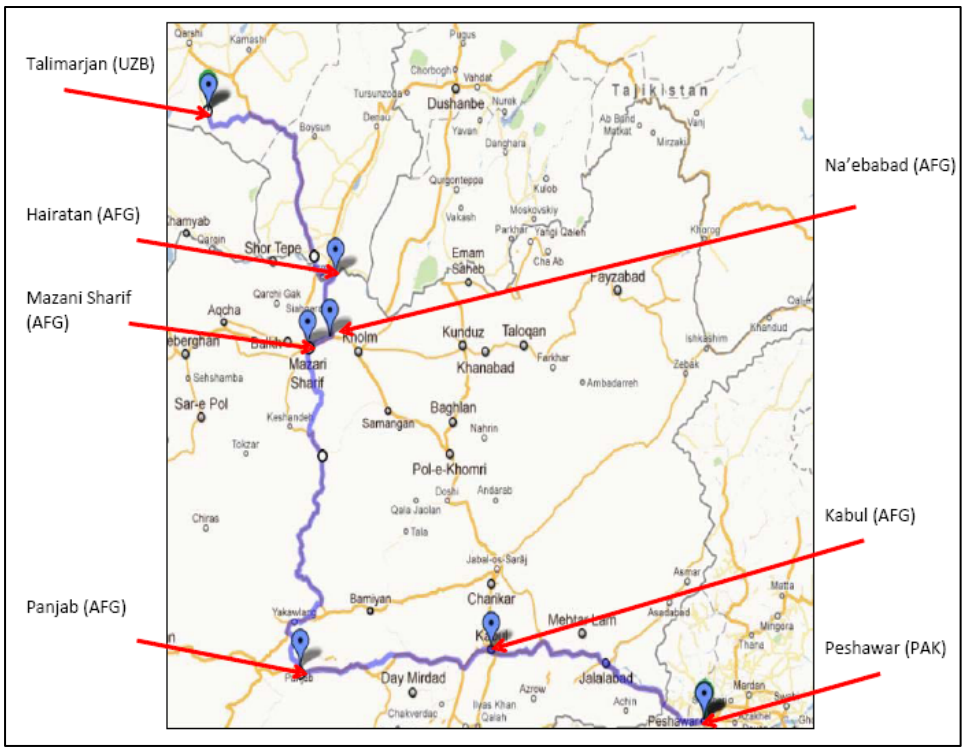
76. As noted in Annex I, is unlikely that making provision for a rail or road network will present any particular constraint on transmission planning. For situations where there is already an existing line and where one or more towers presents an obstacle to a subsequent rail alignment, it is a relatively easy matter to reposition towers without any significant disruption to power supplies. Transmission tower routing would normally take advantage of hilly sites so that spans can be increased as much as possible to reduce construction costs. In Afghanistan, where there is no significant vegetation, spans will range from a typically 350m on flat terrain up to 1km (or more in special cases) across valleys. Thus transmission line alignments are unlikely to be suited to rail alignments although their proximity (within a 1km or so of each other) will reduce the cost of tower foundations and conductor supply and access. Where necessary transmission line contractors usually build short access roads off rail or road routes for access to their optimum tower sites

77. Taking into account the likely development of gas fired generation at Sheberghan or Mazar-e-Sharif there appears to be an even better alternative for an HV line commencing at one of these power stations partly following the road currently under construction by ADB through Bamyan (picking up both Ishpushta/ HajiGak en route) and continuing on to the proposed new 220 kV substation Dasht-e-Barchi. This is similar to a route proposed by SNC/Lavalin for an HVDC line in their March 2012 UAP-EST report (Figure 4.3)

78. This same alignment for a 220 kV line would offer both an alternative route for power supplied from Turkmenistan and facilitate the development of the proposed gas fired power station at Sheberghan. Such a line approximately 400km in length with intermediate substations would be clearly a major investment. Part of the line could be funded under the terms of the MJAM project but co-investment would be required from other financing agencies (possibly the ADB as a quid pro quo for cancelling the duplicate 220kV line). However before deciding on an optimum route for HVAC (220kV or higher voltage) lines it is necessary to take a step back and look at the overall picture of power development taking into account the Bank's immediate interest in supporting the proposals for corridor development.

[43] Even though this is not shown in Table 2.2, ADB is currently recruiting consultants to recommend the best use of the remaining tranche of power sector funding: this should certainly be a strong candidate for funding.

Figure 4.3: HVDC Transmission Line Route proposed in the UAP_EST Study

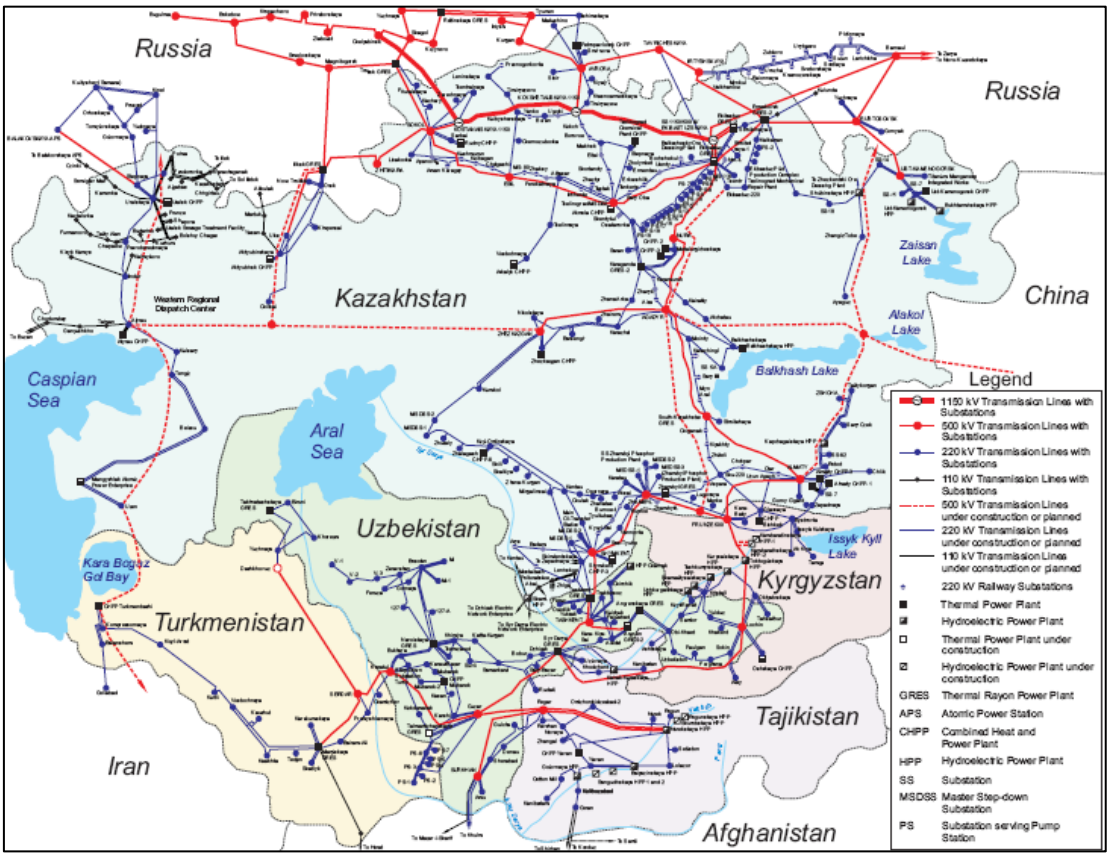


4.2 Constraints of Power Transfers between Asynchronous Systems

79. The fact that all of the neighbouring countries (Turkmenistan, Uzbek, Tajik, Iran, Pakistan) power systems operate separately and therefore asynchronously, presents a significant power supply security problem for Afghanistan. The problem could be resolved quickly if the CAS countries resynchronised with each other through their 500kV network (as they were in former USSR days) and thereby enable Afghanistan to manage its imports of power without interruption[44]. Yet it is unlikely the three CAS countries will form a synchronised power market in the short term since there would be a period while each country has a surplus of generation that would be subject to rigours of competition with its neighbours. Figure 4.4 shows how the CAS could function if they re-established interconnection through their 500kV networks.

[44] These technical issues are currently under investigation by ADB-appointed consultants Fichtner under the scope of a separate study.

Figure 4.4: The CAS 500kV network



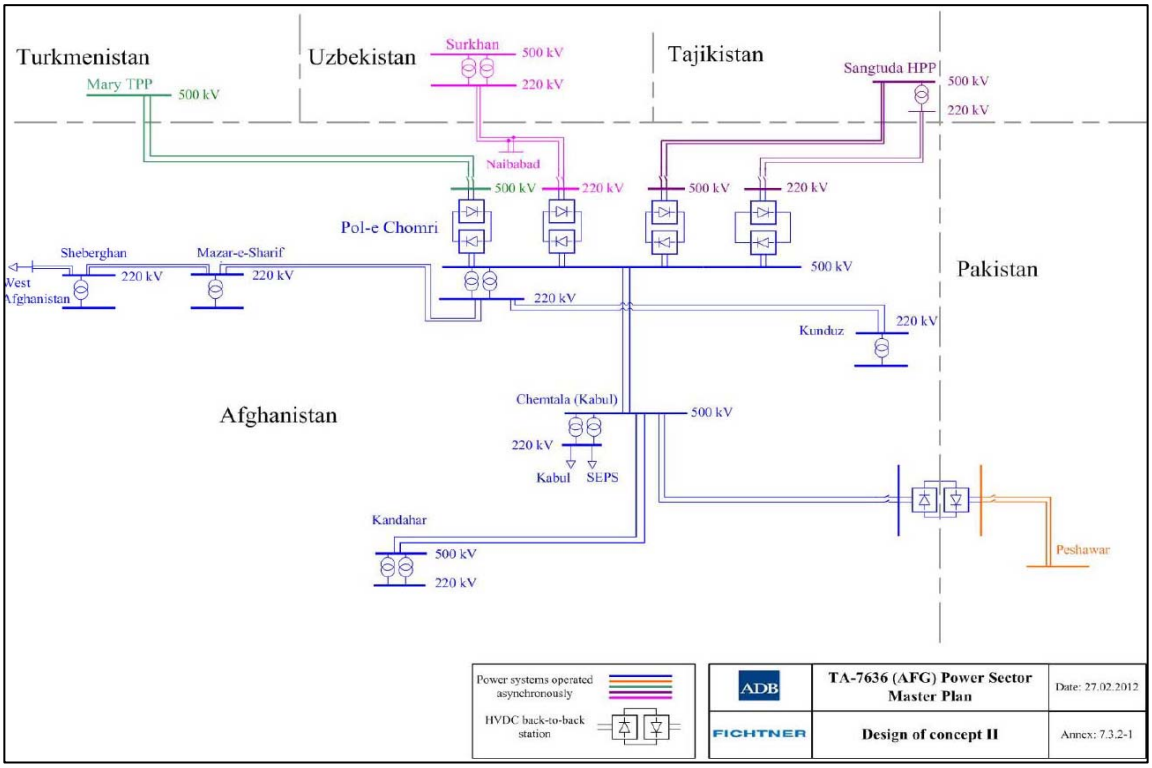
Source: MEW/AEIC

Box 2: Synchronisation Issues

The ability to synchronise all types of electricity generation plant within an integrated alternating current (AC) power system is key to ensuring the most economic operation of a country's generation plant is used to provide reliable supplies to consumers. For a small AC system it is relatively easy to lock one of more generators together by carefully controlling their respective speeds until they are identical and then quickly connecting them together. For a larger power system interconnection must be made according to an established Grid Code for the network to ensure failure of any unit or line does not adversely impact other units in the system. Once interconnected however the respective generators can be readily coordinated by observing common market rules to serve an aggregated regional demand according to their economic or technical advantages. However with large AC systems such as Pakistan or Iran where the synchronous speed (i.e. instantaneous frequency) of each system has enormous inertia resisting change, it is generally not practicable to adjust their respective frequencies in order to effect parallel operation. In these situations interconnection would have to be managed one generator at a time and in the process resulting in unacceptable disruptions in service on one system or the other. Two such large asynchronous AC systems can however be interconnected by connecting them through an HVDC system that converts AC to DC and back to AC again.

80. One way to meet load growth in Afghanistan in the short term would be to continue to synchronise with Uzbekistan, employ HVDC back-to-back converter facilities at Mazar-e-Sharif (to facilitate supplies from Turkmenistan) and use the CASA 1300 MW ±500 KV HVDC link to supply Kabul en route to Pakistan. On the other hand if the CASA project does not progress and/or the country is unable to develop adequate local generation resources, and unless the CAS countries behave more rationally, Afghanistan may have to resign itself to building expensive and impractically complex HVDC systems to effect growth in the market for cross border power exchange (as suggested by Fichtner, Figure 4.5).

Figure 4.5. The HVDC option for CAS



Source: Fichtner Inception report, *op.cit*.

4.3 Proposed Plan to Support and Extend MJAM's Mining and Power Station Project

81. MJAM's contractual obligation to build a 220 kV line from the Ishpushta coal fired plant to the Aynak copper mine represents an opportunity to provide increased diversity and security to Kabul city, the largest load centre in Afghanistan, by (i) building an alternative 220 kV north-south transmission line and (ii) completing a 220 kV ring around the city. To minimise the risk of investing prematurely in transmission works the various components of the project are proposed to be designed to be built to match the associated developments that are expected to proceed over the next few years. The total cost of the minimal configuration 220 kV construction project, including contingencies, is about $184 million (Table 4.2).

Table 4.2: Costs and likely financing

	Financing Requirements for North South Line and Kabul 220kV ring	Finance source	Item in Annex	TL dbl cct route km	Build TL 220kV US$	Build for 500kV T&S US$m	500kV TL for 220kV ops US$m
TL	Mazar-e-Sharif to Ishpushta	TBD	1,2	262	53.5	155.6	102.1
SS	Mazar-e-Shariff 220kV Substation extension	TBD	i		1.4	21.4	
TL	Ishpushta-Bamyan-Dasht-e-Barchi-Anyak-Tarakhil	MJAM	34567	293	59.8	127.7	83.8
SS	Ishpushta-Bamyan-Dasht-e-Barchi-Anyak-Tarakhil	MJAM	ii iii iv v		27.3	81.9	
TL	Chimtala-Dasht-e-Barchi; Chamtala-Tarakhil	ADB/tbd	89	49	10.0		
SS	Chimtala and Tarakhil 220kV extensions	CASA	vi vii		1.2		
	Subtotal MJAM Costs			293	87.1		
	Project Base Costs			604	153.3	386.6	186.0
	Project Costs with contingencies	20%			183.9	464.0	223.1

82. If it is decided to build the north-south transmission line (from Mazar-e-Sharif to Dasht-e-Barchi) using 500 kV construction (for initial operation at 220 kV), there will be an additional US$186m added to the cost of the line. At a later stage when it is appropriate for the north-south line to be operated at 500 kV, it will be necessary to build 500/220 kV substations at the terminals of the line along with a third intermediate substation probably at the Bamyan Valley location with facilities to interconnect at 220 kV to the local demand and generation centres. If it is decided to build the 500/220 kV substations as part of the project the total cost will be $464 million. However this would imply DABS taking a big risk by investing in what may turn out to be unnecessary facilities that may never be used to their full capability.

83. The decision to build a 500 kV line and to operate at either 220 kV or 500 kV will be dependent on the development of key industrial/power projects including (i) a new source of gas fired generation in the vicinity of Mazar-e-Sharif - either from the proposed Sheberghan gas project or via imports from Turkmenistan; (ii) the commissioning of the steel mill (associated with the HajiGak mine) which may be located near Mazar-e-Sharif and include an associated generation plant; (iii) the commitment by Tajikistan to export 300 MW via HVDC supply under the CASA project to a new substation located behind the airport between Tarakhil and Chimtala; and (iv) the commitment by Uzbekistan/Turkmenistan to build an 1,000 MW HVDC line under the UAP-EST project from the border at Hairatan via Kabul to Pakistan.

84. Assuming none of these projects is likely to go ahead in the near term, the minimal 220 kV configuration would be built phased according to associated project

developments (as well as the availability of finance) for subcomponents associated with the integration of the MJAM line with the NEPS.

Table 4.3: Cost estimates

Phase	Scope of Work	Dependence on other Developments	US$ m
1	MJAM builds 220 kV line from 113 MW Tarakhil DPS to Aynak	This line will would be required to provide the initial power to the Aynak mine possibly from the Tarakhil Diesel power station, though not part of the current contractual obligation of MJAM.. The implementation arrangements, including responsibility for maintenance and the timing of the transfer of ownership the DABS will need negotiation.	32.2
2	MJAM builds the 220 kV line from 400 MW Ishpushta plant to Aynak mine	This line is required under the Ministry of Mines contract with MJAM together with an obligation to supply DABS at both Bamyan and Dashti-Barchi. It is noted the supply to Bamyan would also be required to house the MJAM workforce associated with the Ishpushta mine and power plant	72.4
3	DABS builds line from Mazar-e-Sharif to complete north south route	This project would proceed when either Sheberghan gas fired power plant is available; or if power from Turkmenistan is available under a new import contract	65.9
4	220 kV ring around Kabul completed when/if CASA project proceeds	This project could be built either as part of the CASA project to enable an HVDC converter supply to be interconnected with Tarakhil and Chimtala, or as part of Bagdhara hydro project development.	13.5

85. Although project phasing will be determined to a large extent by developments with associated projects, it will be necessary for DABS to take immediate steps to ensure that both its own domestic generating plants and the MJAM power plant can be synchronised together with one or other of the CAS systems (in this case either the Turkmenistan or Uzbekistan grid). This will require an application by the Minister of Energy to his counterparts in the CAS countries to interconnect with the CAS grids. They will in turn require Afghanistan to develop a satisfactory Grid Code and perform a number of power system simulation studies along with associated commissioning tests in both MJAM and DABS power plants. The procedure for applying to CAS to determine their synchronisation requirements is set out in Annex III.

Project Costs

86. Project costs for the transmission lines and substations are derived from the recently completed 164 km 220 kV Sherkan-Pul-e-Khumri project built in 2009 and procured under ICB tendering rules. Project costs for an alternative line built for eventual 500 kV operation are based on estimates derived from the SNC Lavalin report

for the CASA project. The total project costs do not include the cost of the MJAM power station at Ishpushta which, if new, is estimated to cost about $600 million. It is recognised that cost estimation in Afghanistan is fraught with risks of overruns associated with providing security for contractors constructing the lines and the high cost of the logistics of supplying equipment to remote areas over poor road networks. Furthermore in the last few years there has been a significant rise in commodity prices particularly for aluminium and steel. For instance, Norplan's 2004 estimates are just half of today's costs.

87. While the cost of the 220 kV line was based on the equivalent of about $200,000/km, similar lines built by various agencies in Afghanistan have ranged between $180-400,000/km depending largely on location of the line and the source of funding. A recent highly speculative (and rejected) solo bid for the Chimtala to Dashti-Barchi line was estimated at $800,000/km! For preliminary cost estimation purposes a contingency factor of 20% is included in the overall cost estimates.

88. The alternative of building a 500kV line is dependent on the necessary rating as required to transmit power through the north-south corridor at 220kV and ultimately 500kV operation. If it is decided to operate at 220kV the cost does not include provision for the associated 500/220 kV substation extension. The 500/220 kV substations may be required if any one of the following projects proceed: (i) another larger (possibly 800 MW) coal fired project at Dara-e-Suf, just north of Ishpushta[45]; (ii) further gas development and CCGT power plant associated with associated gas in the Afghan-Tajik field; and (iii) significantly increased imports from Turkmenistan. If these projects prove to have any traction there may be case for either building the line suited for 500 kV operation or building a parallel HVDC line along the same route. Both alternatives need to be re-considered once more information is available.

Financing

89. Project financing is likely to be provided from a number of sources. MJAM will obviously be a major contributor including provision for an early start to mining works. In this instance, it would be in the interest of DABS if MJAM were willing to extend its scope of work to include the Aynak to Tarakhil 220kV component to get access to Tarakhil generation. This would enable DABS to use the Tarakhil station in some backup capacity and eliminate the need for MJAM to build its planned 100MW diesel power station as proposed for early start-up operations at Aynak.

90. Bearing in mind the proposed project should also obviate the need to build a duplicate 220 kV line from Pul-e-Khumri to Chimtala (as proposed for ADB financing[46]) there is a plausible argument that the US$ 80 million funds designated by

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45 Dara-i-Suf appears to have the greatest potential for significant reserves, estimated to be over 84 million tons. This coal is believed to be of coking grade with a high calorific value in the range of 7,000 kilocalories/kg.

46 It is understood the ADB is currently (May 2012) recruiting a consultant to recommend how the remaining tranche of its Energy Sector Development Investment Program will be utilized.

ADB be reallocated to the proposed north-south project as detailed above. Other sources of future funding, including co-funding to upgrade the 220 kV line to 500 kV, would also need to be mobilised.

5. The Carbon Footprint

91. A large coal burning power project will significantly increase Afghanistan's greenhouse gas emissions. However, with Afghanistan's present emissions being at the bottom of the global emissions rankings (by whatever criterion is used), and given the global community's overriding interest in securing a sustainable development strategy for Afghanistan, this Section will show that, in this instance, the World Bank's screening criteria for supporting coal projects are easily satisfied.

5.1 GHG emissions

92. According to the World Bank database,[47] per capita emissions are too small to be recorded (shown as zero!). The most recent detailed presentation of GHG emissions dates to 1998 which shows the breakdown shown in Table 5.1. The UN gives a GHG emission figure of 714,000 tons for 2007.[48]

Table 5.1: 1998 Afghanistan GHG emissions

	1000 tons
Solid fuels	4
Liquid fuels	689
Gaseous fuels	264
Gas flaring	22
Cement	58
Total	1,037

Source: *earthtrends.wri.org/pdf_library/country_profiles/cli_cou_004.pdf*

93. International comparisons are shown in Table 5.2. In terms of tons/capita, Afghanistan ranks at the bottom of the list with emissions less than 0.1 tons/capita, together with the poorest 4 African countries.[49] It can thus be stated with confidence that by any reasonable global yardstick, Afghanistan's GHG emissions are negligible.[50]

94. Suppose 1,000 MW of additional coal generation were in place by 2020. Assuming an 80% load factor, this would result in total annual emissions of 7.01 millions tons of CO_2.[51] While there is uncertainty about population and population growth rates, assuming a present population of 35 million, and a 1.5% growth rate, brings the 2020 population to 39.4 million, and hence per capita GHG emissions of 0.18 tons/capita. That would barely change the Afghanistan's global ranking, which

47 http://data.worldbank.org/indicator/EN.ATM.CO2E.PC

48 UN 2010 World Statistics Data book, Country Profile Afghanistan

49 Mali, Chad, Burundi and the Democratic Republic of Congo.

50 There is much uncertainty about population size. The World Development Indicator (WDI) database gives the 2010 population as 34.4 million – which value is used in this report unless stated to the contrary.

51 Assuming a gross emission factor of 1kg CO_2/kWh.

increases marginally to join a group of countries that includes Togo, Haiti and the Gambia.

Table 5.2: International comparisons, CO_2 emissions per capita (2008)

	TonsCO_2/capita
USA	18.38
Germany	9.79
South Africa	6.93
China	4.92
Global average	4.39
Vietnam	1.19
Sri Lanka	0.61
Afghanistan(1991)	0.2
Afghanistan (2020)(1)	0.18
Afghanistan (1998)	0.03

(1) assuming an additional 1000MW of coal generation, see text below

95. Afghanistan's per capita (GNI) income is estimated by the World Bank at $528[52]: the World Bank' WDI database shows Afghanistan ranking 184 of 190 countries in 2009. Consequently it is no surprise that emissions per unit of GNI has similarly low values: for Afghanistan the World Bank WDI database[53] shows 0.026 Kg/$GDP(PPP adjusted), ranking bottom of the 181 countries for which 2008 emission data is available.

96. It is obvious that Afghanistan's GHG emissions are negligible, even with 1,000 MW of additional coal-fired electricity. It is also worth noting that on a net rather than gross emissions basis, coal-fired electricity that would be generated at the mining power projects for NEPS in fact replaces kerosene (domestic lighting) and diesel (for self generation), whose GHG emissions are at least half those of coal. Moreover, if the ores were processed not in Afghanistan, but in a neighbouring country, power generation and GHG emissions in Afghanistan would indeed be lower, but offset by the power production in the receiving country – which most likely is China or India, both heavily dependent on coal power generation.

5.2. Coal project design

97. Thus far, MJAM has said little about the coal generating project design except to say that it will be "environment friendly, high capacity, high dimension, high efficiency". Absent information to the contrary, one can perhaps assume that the plan is to install 150-300 MW units of older Chinese design, with sub-critical steam

52 Given the uncertainty in the population of Afghanistan, the *per capita* GNI figure is also similarly uncertain. The last official census was in 1979, but even that was not completed (for reasons of the Soviet invasion). The World Bank's World Development Indicator (WDI) data base gives a 2010 figure of 34.4 million. The CIA Fact book gives a mid-2012 estimate of 30.4million. The UN Population Department gives a 28.1 million figure for 2009. The Government's Central Statistical Office estimates the 2011 population at 24.9 million, and suggests a population growth rate over the past six years of 2.1%

53 {EN.ATM.CO2E.PP.GD.XLS}

conditions, and from still existing manufacturing lines in China (no more used in China, but still being promoted for export overseas, such as the 285 MW coal project recently completed in Sri Lanka by a Chinese consortium). These are robust units and reliable designs, and easy to maintain, but are less efficient than the super critical and ultra-super critical units now being built in India and China.

98. Typical supercritical units run at around 41% efficiency, compared with typical sub-critical efficiencies of 38%, which implies GHG emissions about 8% lower per net kWh sent out. This is typically achieved at a somewhat higher capital cost, typically 2-4% greater. But even without taking into account GHG emissions, super-critical units are the cost-effective choice for large plants.

99. The most important constraint to supercritical units in Afghanistan is size. We know of no supercritical unit in Asia of less than 600 MW: in India, the smallest supercritical project is 2 x 660 MW, and many use 800 MW units. The first supercritical unit of Chinese design is 600 MW (at Huneng Qinbei, 6 x 600 MW in 2004); those offered by non-Chinese vendors are all greater than 600 MW.

100. None of the mining projects warrant so large a scale, nor does the system size in Afghanistan. To impose a requirement for a single 500-600 MW unit in place of 2 x 250 MW or 3 x 150 MW would be unreasonable, and likely to be unacceptable. That neither India and China still build sub-critical coal units for domestic use has no relevance to Afghanistan.

101. Another constraint is that supercritical units require a higher level of sophistication in construction and operational maintenance than conventional sub-critical units. For the type of remote location envisaged, with long supply routes for spares, this would impose significant problems for MJAM.

102. Nevertheless, even for sub-critical technology, a reasonable level of efficiency should be imposed: the PPA can readily assume a normative heat rate for the cost calculation which would provide an incentive for the operator to operate at maximum efficiency.

5.3 World Bank screening criteria for coal projects

103. Would a sub-critical coal project meet the recently promulgated World Bank screening guidelines for coal projects?[54] The six criteria, and the degree to which they are satisfied in the case of Afghanistan, are as follows:

1) <u>There is a demonstrated developmental impact of the project, including improving overall energy security, reducing power shortage or increasing access for the poor</u>*;* The rationale for resource corridor development is grounded in the mining sector; the global community's interest in securing a sustainable future

[54] *Criteria for Screening Coal Projects under the Strategic Framework for Development and Climate Change'* Operational Guidance to World Bank Group Staff. March 2010.

for Afghanistan; the country's miniscule level of GHG emissions; the current extent of severe power shortages; the excessive dependence on imports posing great risks to energy security; are all so compelling that the developmental benefit far outweighs any reasonable valuation of the incremental GHG emissions.

2) Assistance is being provided to identify and prepare low carbon projects: As noted, several donors have identified and are supporting a variety of renewable energy projects in rural areas, and several hydro projects, both new as well as rehabilitation of existing plants, are also underway.

3) Energy sources are optimised, looking at the possibility of meeting the country's needs through energy efficiency (both supply and demand) and conservation. Given the extremely low per capita consumption of electricity, the chances of meeting the potential demand through energy efficiency alone are nil. The donor community is making a large effort to provide funding for rehabilitation of the dilapidated distribution system which will result in significant reduction in T&D losses, and improve the GHG emissions efficiency of the sector.

4) After full consideration of viable alternatives to the least cost options (including environmental externalities), and when the additional financing from donors for their incremental cost is not available. There are few viable alternatives in the short- to medium term: the feasibility of the larger hydro project alternatives have yet to be demonstrated (and are likely to have significantly higher cost, and bring their own set of environmental externalities). The gas resource is still of uncertain size and its use for power generation brings additional opportunity costs associated with the use of gas for fertilizer manufacture or for household use (in which application it avoids significant local environmental externalities associated with the use of firewood and diesel, or even to replace the widespread - and highly polluting - use of used tyres as a fuel for brick making).

5) Coal projects will be designed to use the best appropriate available technology to allow for high efficiency and, therefore, lower GHG emissions intensity; For reasons explained above, super-critical (and ultra-super-critical) technology is not appropriate for Afghanistan for the first set of projects to be developed by the mining concessionaires. T&D loss reduction is likely a more cost-effective strategy to reduce net emissions per kWh delivered to consumers than supercritical coal generation (assuming that in fact this technology were appropriate).

6) An approach to incorporate environmental externalities in project analysis will be developed. A methodology to be used for evaluating alternative power sector development scenarios is underway.[55]

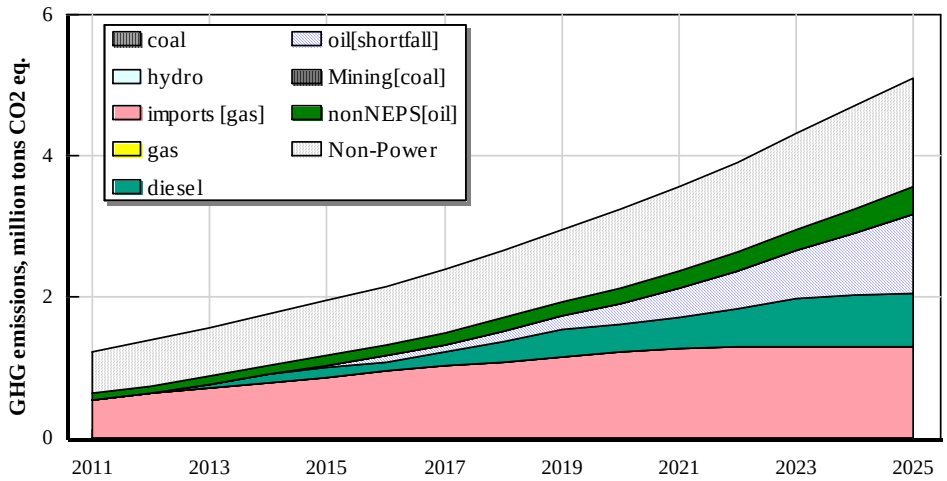
[55] To be developed as part of the forthcoming ESMAP study.

5.4 GHG emission consequences of generating technology choices

104. The calculation of gross GHG emissions associated with the combustion of fossil fuels is straightforward, and emission factors are based on IPCC defaults. It is assumed that imports from the central Asian republics are based on gas (and whose emission factors are subject to an additional 2% transmission loss penalty); any hydro surpluses are assumed exported to Pakistan, where they are assumed to displace natural gas based CCGT (and again adjusted for transmission losses).

105. Figure 5.1 shows gross GHG emissions for a baseline scenario (with no new generation projects, and continued and increased reliance on imports). This assessment makes the assumption that a combination of affordability constraints and diesel fuel availability means that only 50% of the potential demand for electricity substitutes (kerosene for lighting, diesel for self-generation) is in fact met (and shown in the figure as "oil, [shortfall]". Emissions identified as "Mining Sector" represent that part of (coal based) generation used for the mining operations. 2025 emissions per capita are just 3% of the global average, while emissions per dollar of GDP are 26% of the world average.

Figure 5.1: GHG emissions baseline scenario (imports only)



	GHG emissions lifetime(1) million t	2025 million t
NEPS	45.6	3.2
Mining sector (2)	0.0	0.0
non NEPS power	5.6	0.4
other	24.6	1.5
total	75.9	5.1

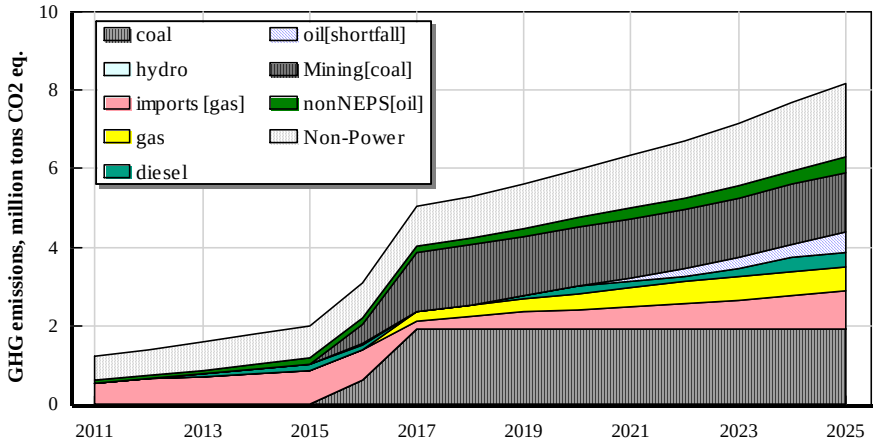
(1) 2011-2030
(2) Emissions from own use of power plants

Indicators	world average 2009	Afghanistan 2025	%world average
GDP/capita, $US	9135	1017	11%
Population, million		43.1	
total GHG, kg/capita	4.73	0.12	3%
total GHG, kg/$GDP	0.44	0.12	26%
kWh/capita	8722	186	2%

106. Figure 5.2 shows the corresponding emissions pattern when the coal generation projects of the resource corridor are added. Lifetime emissions have increased significantly from 76 million tons to 119 million tons, but when compared to the global average, per capita emissions are just 4% of the 2009 global average. The per capita

GDP is higher than in the baseline, under the assumption that the resource growth corridor improves the post 2014 GDP growth rate from 5% to around 6.8%.[56].

Figure 5.2: GHG emissions: baseline +resource corridor projects



	GHG emissions lifetime(1) million t	2025 million t
NEPS	62.9	4.4
Mining sector (2)	21.7	1.5
non NEPS power	5.6	0.4
other	29.0	1.9
total	119.2	8.2

(1) 2011-2030
(2) Emissions from own use of power plants

Indicators	world average 2009	Afghanistan 2025	%world average
GDP/capita, $US	9135	1236	14%
Population, million		43.1	
total GHG, kg/capita	4.73	0.19	4%
total GHG, kg/$GDP	0.44	0.15	35%
kWh/capita	8722	186	2%

5.5 Conclusions

107. While one should be mindful of the environmental and GHG emission impacts of the development of Afghanistan's coal resources, if there is one country in the world where economic development and energy security considerations outweigh GHG emission reductions, and where the criteria enumerated in the World Bank guidelines for consideration of coal projects can be met, it is surely Afghanistan. Even with the development of coal 1,000 MW of coal-based generation (as might be associated with the development of the Aynak and HajiGak mining projects, plus 100-200 MW for use by NEPS), Afghanistan's gross emissions, emissions per capita, and emissions per unit of GDP are miniscule, and rank at or very near the bottom of all global comparative indicators.

108. On the specific question raised by the ToR of whether a requirement for supercritical coal technology should be imposed, the answer is clearly no. While GHG emissions would indeed be lower, supercritical units are simply not available in unit sizes below 600 MW – and even were the mining projects to generate a total of 500-600 MW, to request a single 600 MW unit in place of 2 x 250 or 3 x 150 would be unreasonable. However, as discussed above, it would not be unreasonable to impose a heat rate requirement under the PPA for sales to NEPS.

[56] World Bank: *Afghanistan in Transition: Looking Beyond 2014*, May 2012

109. The priorities for ensuring a sustainable development path for Afghanistan's power are as thus as follows:

- Investment on rehabilitation of the distribution system. Bringing down T&D losses from the present level of 35-40% is clearly the first priority not just from the perspective of minimising GHG emissions, but also from the perspective of reducing the need for generation investments and imports. This is the most obvious win-win option (and will be documented by the forthcoming ESMAP study).

- Development of the larger hydro projects would reduce GHG emissions. However, whether these are realistic options from an economic standpoint, and from the standpoint of hydro-related environmental impacts, remain to be confirmed. The priority is for modern feasibility studies and impact assessments to be completed, in the absence of which it cannot be stated whether these larger hydro projects are realistic alternatives.

- Emissions from gas-fired power plants are lower than from coal projects (higher efficiency of CCGT, lower GHG emissions per unit of calorific value than from coal). But there remain questions about the size of the Sheberghan gas resource, and whether the resource is best used for power generation. If the Sheberghan gas project simply replaces gas imports from Uzbekistan, the impact on GHG emissions is limited to the differential transmission losses associated with the transmission line from Uzbekistan.

6. Regulatory and institutional requirements

6.1 Institutional and regulatory framework

110. Currently the Ministry of Energy and Water (MEW) is responsible for policy, planning and investment. Independent regulation of the power sector as proposed under Afghanistan Energy Regulatory Authority (AERA), currently in development, is key to the long-term viability of Afghanistan's power sector.

111. In 2008, Da Afghanistan Breshna Sherkat (DABS) was established as a wholly-owned government-joint-stock company recognized as an energy utility, responsible for energy production, power transmission and distribution of electricity throughout Afghanistan. The national utility is managed by a Board of Directors (Board) that provides a fiscal framework for energy policy development, facilitates coordination between stakeholders, and works in partnership with GIRoA. The internal management and operations of the utility are currently being reorganized to enable DABS to function as a commercial enterprise. DABS is aggressively adopting transparent operational procedures, installing a state-of-the-art computer network, and requesting third party auditing and financial statement certification.

112. In order to address strategic policy and planning needs of the GIRoA, extensive support will be provided to the MEW and AERA to build capacity to develop strategic policy through technical assistance and training. Capacity development efforts will focus on key Ministry and AERA staff. Strengthened capacity of MEW and AERA to properly plan and regulate the energy sector will support the creation of a favourable investment climate. Technical assistance will be contracted to support the MEW in energy forecasting and policy development, in support of program design, implementation, monitoring, quality assurance, and other matters.

6.2 Grid code

113. A Grid Code is a technical specification which defines the parameters an electricity generating plant has to meet to ensure proper functioning of the electrical grid. The authority responsible for the electricity distribution specifies the grid code which may vary from country to country. Grid codes have become increasingly popular over recent years partly due to the needs to interconnect new types of generation such as PV and wind which have characteristics that place unusual or intermittent demands on the power system.

114. In countries such as Afghanistan a grid code is also necessary to define appropriate power system design parameters and interconnection standards so as to minimise the use of different types of power equipment that are often introduced by donor countries. In this respect Afghanistan's existing legacy of power systems designs comprise a mixture of voltage levels; the HVAC transmission level includes 35 kV, 44 kV, 110 kV, 132 kV and 220 kV. MV systems are supplied at 6 kV and 15 kV with the

latter built for eventual upgrading to 20 kV. A summary of the technical standards for the main voltages used in Kabul city is given in Annex II.

115. The objective of the code is thus to set a common basis for satisfactory operational reliability and quality of supply for all participants in the electricity industry. It concerns the operation and planning of the Transmission System Operator's electric power system and the market participants' access to the grid. A code should be designed to permit the development, maintenance and operation of an efficient, coordinated and economical system for the transmission of electricity, to facilitate competition in the generation and supply of electricity and to promote the Scheduling and Dispatch Code, Data and Information exchange code and the Metering Code.

116. A Grid Code for Afghanistan, acceptable to its neighbours, should detail the following:

- Rights and responsibilities of the transmission enterprise; the Power System Operator, electricity generators; customers connected to the transmission system; the public provider; public suppliers and electricity traders,
- Technical requirements for connection to the transmission system for both materials and staff
- Procedures of transmission system development planning and use;
- Procedures of Power system operation planning
- Scheduling and control of Power System (PS) operating mode; development and performance of a defence plan and of a plan for PS restoration;
- Procedures of mandatory data interchange, sequence of on-line data interchange, and on-line power system control
- Activities of the PS operator and of transmission system Users related to the quality control of PS operation;
- Conditions and procedures of system tests, certification of systems Provision of complementary services
- A cost-effective framework for dispute resolution for all code participants
- Adequate sanctions in cases of breaches of the Grid Code;
- Efficient processes for changing the Grid Code;
- Technical, Safety, security and performance standards with regard to the PS and protection systems
- Codes of practice covering the construction, operation and maintenance of electro-mechanical components of transmission and distribution systems
- Codes of practice for customer services related to the electricity supply industry
- Responsibilities in case of accidents
- Responsibilities in case of losses and compensation
- Other relevant activities related to the overall PS operation process

7. Conclusions and Recommendations

Power sector issues

117. Afghanistan's power supply is excessively dependent on imports. For the last five years electricity consumption has grown by 19% per year. However this has been achieved primarily by increased imports from Uzbekistan (as well as from Iran, primarily to serve central Herat, and smaller amounts from Turkmenistan). In 2011, 77% of supply in the Northeast Power System (NEPS) was from imports. The generation mix needs to be diversified, not just from an energy security point of view, but also because of potential limits on additional future imports as domestic electricity demand in Uzbekistan grows. The only new domestic generation project (105 MW diesel project at Tarakhil completed in 2010) has been little used for reasons of high operating cost and fuel shortages. It is expected that the 42MW Salma hydro project will commissioned later this year, but this will serve the Herat system, not NEPS.

118. Grid Code for Synchronous Operation: Afghanistan's export contract with Uzbekistan expressly forbids DABS from synchronising domestic generation plant with the Uzbek system. Likewise the contract with Turkmenistan stipulates that HV transmission facilities in Afghanistan must have "identical technical characteristics ….". In effect this means that Kabul is currently supplied from two separated sources; part from the Uzbek system and part from its own domestic generation. This is an intolerable situation for many Kabul consumers who complain of the continuous fluctuations in the supply (largely due to the unstable local generation capability). The reasons for the export countries' concerns is that Afghanistan does not have a credible Grid Code that ensures transmission and generation equipment are adequately protected, and load shedding arrangements are in place to ensure that local system failures do not cascade into and disrupt the CAS grid operations. It is understood that existing rehabilitation plans at the hydro plants like Naghlu provide for the installation of appropriate protection equipment, but more will need to be done to ensure the compatibility of transmission protection and the adequacy of communications links between major substations and the respective Load Dispatch Centres.

119. **For the next decade or so Afghanistan will depend on imported power that will need to be integrated with the generation mix made up of an increasing contribution from local resources**. Given the asynchronism issues, the long distances involved (coupled with the inherent operational constraints of long HVAC transmission lines) and the power transit opportunities, there is no doubt that HVDC systems in some form or another will be part of any future Afghanistan transmission system. HVDC systems can however can be readily integrated into the design of the Afghanistan power system either in parallel with the HVAC systems or via HVDC terminal and B/B facilities but must also be a consideration in developing the Grid Code. These issues will need to be addressed urgently to ensure that MJAM's proposed project can be synchronised with the Uzbek grid to become an integral part of the

Afghan generation mix. Accordingly DABS/MEW needs to make an application to join the CAS operational networks as soon as possible.

120. **Various HVDC projects have been proposed to bring electricity generated in the Central Asian States to Pakistan, with some proportion made available to Afghanistan at Kabul.** The Uzbekistan-Afghanistan-Pakistan Electricity Supply and Trade Project would deliver 100 MW (915 GWh) to DABS at a substation North of Kabul and 900 MW to Pakistan in the Peshawar area. The CASA-1000 project would deliver up to 300 MW of surplus hydro power from Tajikistan and Kyrgyzstan, also by HVDC to Kabul, and a further 1,000 MW to Peshawar. Both projects offer various technical advantages to Afghanistan, particularly in terms of how they may be used to deal with the synchronisation problems and how they can supply a diversified source of bulk power over long distances to the major load centre in Kabul. However, the financial and economic aspects of these import/transit schemes need further analysis, particularly to ensure equity among the participants.

121. HVDC Back-to-Back (B/B) connections and associated 500kV lines as proposed in the Master Plan can facilitate the development of a separately integrated HVAC domestic system - but the proposal has significant drawbacks in the longer term. In the first place the capacity of the HVDC B/B facilities may need to be designed to facilitate power trade to Pakistan if this comes about. As such the interconnection capacity will be far in excess of the current requirements for Kabul and will require DABS to make a significant upfront investment without necessarily any guarantee it will earn adequate revenue through power transit wheeling operations. The project concept also implies that supply to Kabul will be dependent on the security and reliability of a number of technically complex HVDC B/B installations at Pul-e-Khumri and on a vulnerable 500 kV line over the Salang Pass. Even worse if the CAS countries decide to resynchronise and establish a common power market (as they are technically capable of doing through their existing 500 kV AC networks) the HVDC B/B facilities will become stranded assets. The larger question is why should DABS go to great expense at its own risk to convert to HVDC (and back again) if it can not take advantage of the significant benefits HVDC transmission offers?

122. Transmission planning should take into account the need for diversity and security of supplies, recognising that in the short term the cheaper imported power from unsynchronised sources needs to be managed so as to maintain competitive prices through flexible off-take designs. A key activity to improve power quality and reliability is to seek approval from the CAS countries to synchronise local generation to the import grids. In the meantime until such time as HVDC sourced supplies to Kabul are available, separate HVAC sources will have to be used to supply separate sections of the Kabul network with flexible switching arrangements to facilitate changes in supply sources. The best way to do this would be to build a new 220 kV line from Mazar-e-Sharif to the southern side of Kabul making full use of the MJAM obligation to build such a line from Bamyan to Kabul on to Aynak. The 220kV line to Aynak would also enable the extension of 220 kV from Aynak to Tarakhil to complete an important section of the recommended 220 kV ring around Kabul. It is however necessary to recognise there are significant benefits to building an HVDC line (based on a long term power transit agreement) and operating it in parallel to the HVAC

system. It should provide an alternative source of power supply in case service from the less reliable main 220 kV line were disrupted anywhere along its route, and will be capable of injecting high speed reactive support to enhance the capability of all AC lines supplying Kabul.

123. Hydro is a potential supply option, but feasibility and costs are uncertain. The 2004 Master Plan recommended the development of two larger hydro projects (Surobi-II, 180 MW, and Bagdara, 280 MW), but most of the studies for potential hydro candidates date to the 1980s, and some require more comprehensive feasibility studies before costs, hydrology, and environmental impacts can be reliably stated. An update of the Master Plan is currently underway: one of its more important tasks is to review candidate hydro projects, and suggest 2-4 candidates for the urgent preparation of new detailed FS suited for financing. Such hydro projects can unlikely be developed as pure IPPs, and can only be implemented as private-public-partnerships (PPPs): this implies that the Government of Afghanistan's share of the investment cost would need to be mobilised from IFIs and donors.

124. The prospects for development of the Sheberghan gas field for power generation remain unclear. There are other competing uses for this gas (fertilizer, household) if the current estimates of reserves can be confirmed. The gas is sour, requiring treatment before it can be used in modern gas machines: whether CCGT or gas engines is the best technology choice requires further study. Indeed, it may well be that the technology choice is influenced by the implementation model: it may be easier to find an IPP to build a modular plant (with 20 MW gas engines) than to implement a 200 MW CCGT (whose combined cycle also requires water). For reasons noted above, this would be a useful power project from an energy diversification perspective, but if CCGT can be generated in large 1,000 MW projects in Uzbekistan, for which there are substantial scale economies, the better strategy would be to diversify with one of the proposed resource corridor coal projects, or with HVDC imports from the CAS. In short, optimum utilisation of the Sheberghan gas requires a broader energy sector perspective, not just that of the power sector expansion plan.

125. Estimates of the production cost of gas remain uncertain. According to the most recent study on the costs of developing the gas field ($124million), levelised over 20 years for the proposed 200MW Sheberghan project results in a production cost of $1.5/mmBTU. This is significantly lower than the Uzbek border price of gas at $8.2/mmBTU. It follows that even if actual production costs prove to be double or triple this estimate, power production at Sheberghan would be attractive. However, whether this reflects the opportunity cost of gas used for households or for fertilizer production is unclear. Gas pricing policy in Afghanistan is at an early stage of discussion, and given the uncertainty about the resource, estimating an appropriate depletion premium is speculative.

126. The prospects for other gas fields such as Amu Darya and Jurasik appear more promising. If, as some studies have suggested, a large CCGT plant (800-2,000 MW) were feasible in the medium to long term (2020 onwards), then this would have a significant impact on the design of any transit project, probably resulting in a much

higher HVDC voltage level to cater for the combined power supplies from Kyrgyz Republic, Tajikistan as well as potentially from Turkmenistan and Amu Darya. This question will be clarified once the ongoing gas field assessments are completed.

127. The present level of T&D losses is unacceptable. Estimates of T&D losses range from 30-40% but without disaggregated sales data it is impossible to make a proper assessment. Total generation and import figures are generally reliable, but DABS has in the past been reluctant to provide such data on sales. Given the state of physical dilapidation of the distribution system high technical losses are not unexpected, and will require significant investment for rehabilitation to modern standards. But the reduction of non-technical losses is a matter largely of management, and the political will to implement anti-theft measures. Experience in other countries shows reduction of T&D losses bring high economic and financial benefits.

The Resource Corridor power generation projects

128. The amount and cost of power from the MJAM project is still uncertain. MJAM has undertaken to build a somewhat larger coal-based power generation projects than necessary for its own requirement: between 100-200 MW would appear possible for supply to the Kabul region, subject to confirmation of the coal resource. The MoU with MJAM states that the price will be by mutual agreement of the Parties, and there are understandings that a PPA should be negotiated, but such negotiations have not yet started. The expectation is that the cost to NEPS would be significantly below the cost of Uzbek gas-based imports, currently at 7.5 UScents/kWh.

129. The impact of the AFISCO iron ore project is similarly uncertain. It would not likely build a coal plant for its own use, and if the project is limited to just ore mining and shipping, its electricity needs would be small (about 50 MW). If steel is to be manufactured, then the project may be either be a net electricity exporter (if it uses the blast furnace conversion process, because town gas from coking and producer gas from the blast furnace can be used for generation) or a net gas importer (if it uses the DRI process), or both (if there were surplus natural gas it might supplement the producer gas from the blast furnace processing to make electricity in a CCGT).

130. Transmission alignments need careful assessment. The proposal to build a duplicate 220 kV line across the Salang Pass appears to be motivated by the fact that it is demonstrably possible to do so and it will be adjacent to a major road. While the existing 220 kV line is undersized for bulk transit of power, there are other feasible routes that have the advantage of providing a more direct source of power from domestic generation plant while providing the Kabul power system greater security through diversity. Thus rather than duplicate the capacity of the line with a parallel 220 kV line along the same route, for technical reasons it would be better to use the proposed CASA line to provide bulk power to Kabul en route to Pakistan. On the other hand the "UAP Supply and Trade Project" has identified a parallel north-south route which could also be used for new 220 kV line providing an opportunity to build substations en route and interconnecting with the proposed MJAM line. It should be

recognised that while there are advantages in building transmission lines near roads, cross country alignments can significantly shorten routes and thereby reduce costs. In this regard Afghanistan has unique topographical features that facilitate cross country transmission construction. There is little vegetation, there are many hills offering the prospect of long spans, and cross country access without proper roads is feasible for construction especially when carried out in conjunction with helicopter operations.

131. The Salang Pass is not expected to be a significant constraint to resource corridor development from an electricity perspective. Notwithstanding the concern that power transmission, road and rail network development would be constrained by the difficult and mountainous terrain, the pass is far too steep for a rail connection, and there is adequate space for more than one run of transmission towers (and were there any space constraints, they can be engineered around at minor incremental cost). On the other hand the existing road tunnel under the Salang Pass appears to have adequate ceiling space for supporting a limited number of cables. An investigation should be performed into the feasibility of suspending two HVDC cables into the tunnel thereby bypassing the most difficult section of the line.

132. **The strategic importance of the North-South link should be noted**, and if a new route across the Hindu Kush were to be proposed, consideration should be given to provide for a service tunnel for HVDC power transmission, fiber optic cable, or even a gas pipeline (if the Amu Daryu gas were sufficient and economic to bring to Kabul). And if it were decided to build a second road tunnel under the Salang pass, provision could be made for a second double circuit 220 kV to traverse through the second tunnel. Indeed, the preferred route for the proposed CASA-1000 project is via the Salang Pass (or through the tunnel) –whether or not a second 2 x 220 kV transmission line is also routed across this pass.

133. The resource corridor coal projects will increase carbon emissions, but GHG emissions per capita or per $ of GDP will remain among the world's lowest. By 2025, the resource corridor projects would increase per capita emissions from the present 0.10 tons/capita to 0.18 tons/capita (based on a 1.5% annual population growth rate): this compares to a 2009 *world* average of 4.4 tonsCO_2/capita. Supercritical coal technology would in principle provide higher efficiency (typically 42-43% efficient compared to 36-37% in the sub-critical units that can be expected) and lower GHG emissions, but the minimum unit size is around 600 MW, and therefore not suitable for the resource corridor. No supercritical coal project in Asia is smaller than 2 x 500 MW. Efficiency can be incentivised by a normative heat rate requirement in the power purchase agreements for sales to DABS. Moreover, equivalent improvements in GHG emissions can be achieved by reducing technical losses in T&D with far greater benefit for the system as a whole.

Recommendations

134. The main recommendation of this report is to forgo at this time the proposal to duplicate the existing 220 kV line from Pul-e-Khumri to Kabul. Instead it is proposed to build a new north-south 220 kV line (or possibly a 500kV line operated initially at 220 kV) from the northern city of Mazar-e-Sharif. The line would traverse through Bamyan township, connecting to the Ishpushta power station en route to Kabul South East substation, and thence to the Aynak copper mine. As the first step in its development it is also proposed to complete the 220 kV loop around Kabul by connecting Aynak back to Tarakhil power station to enable the Aynak mine to use Tarakhil for start-up purposes. There should be provision in the design of the 220 kV north-south line for supplying power to the proposed iron ore mine near Bamyan, and interconnecting other coal fired stations in the area. The technical details of such an approach will of course await the outcome of further dialogue with MJAM power designers, but this approach would have the advantage of facilitating additional generation resources at Sheberghan gas fields and providing greater diversity and security of supplies to Kabul as well as relieving potential overloading on the existing Mazar-e-Sharif to Pul-e-Khumri section of the 220 kV transmission line.

135. We recommend the following steps be taken to resolve some of the main uncertainties over power supply and transmission in the resource growth corridor

- As a matter of urgency DABS needs to establish and implement a Grid Code satisfactory to the CAS countries to ensure it can synchronise existing and future generating plant to the respective CAS networks. The procedure as summarised in Annex III is well defined and an application should be made through the management of the Russian based IPS/UPS grid system to the respective governments of the CAS countries

- MJAM and the Government need to start the negotiations on a power purchase agreement as soon as possible, which on the Government side need to include DABS, MEW as well as MoM. As noted above, the PPA should contain a stipulation on normative heat rate to provide an incentive for efficient utilisation of the coal resource. Moreover, even if MJAM argues that the specific cost numbers must await completion of its resource assessment, discussion about the principles that should be used to calculate the power tariff can begin immediately

- An important question for MJAM concerns the ability of Government to commit to a firm timetable for transmission line connections, both to provide start-up power for Aynak, and for power evacuation arrangements for the coal project. The penalties for non-performance (of *either* party) to adhere to a mutually agreed implementation timetable will be one of the critical issues to be negotiated, but this requires clarity about DABS/NEPS transmission planning.

- The extent to which the larger hydro projects do in fact represent reasonable generation supply options cannot be assessed in the absence of modern feasibility studies. 2-4 such hydro candidates should be identified, and, as

necessary, existing feasibility studies be reviewed and updated, so that decisions about these projects can be made on the basis of reliable modern assessments.

- There must be sufficient flexibility built into the design of the HV transmission network to cater for changes in the way in which domestic power generation projects are likely to develop. Along the alternative 220 kV north-south route through Bamyan/HajiGak there should be provision to uprate AC line voltages to 500kV where appropriate. Similarly the HVDC designs should also be able to be uprated without having to resort to re-insulation or re-conductoring under load.

- If the HVDC regional trade projects are to move forward, which we believe would offer some significant advantages to Afghanistan, then the economic and financial analyses of the present proposals (CASA-1000, UAP and TUTAP) need to be revised and extended. In the absence of realistic tariff proposals based on an equitable apportionment of costs and benefits, and a full understanding of their distribution among the parties, it will be hard for the Government of Afghanistan to take an informed view of the proposals, and include them in their power sector expansion plans.

- More importantly, the Government needs to start the negotiations with the CAS countries and Pakistan on a power purchase and transit agreement (PP&TA) before proceeding with any supplementary investment (e.g. HVDC B/B or 500kV lines or HVDC lines) that is needed to support the transit operations.

- Reducing T&D losses, and particularly non-technical losses, has to be an immediate priority, with high net economic benefits as well as significant reductions in GHG emissions. The benefits accrue regardless of the choice of supply or transmission options.

- However, to formulate a cost-effective loss reduction plan requires sales and collection data that is currently not released by DABS. We recommend that this information be made available to consultants and the wider investment community working in this area: most utilities make such data available.

- There is substantial self-generation capacity in Afghanistan, and based on similar experience in other countries the aggregate capacity of captive plant will be at least as much as the existing demands in the city and often presents an opportunity for the utility for co-operation in handling peaks when supply is limited. It is recommended that captive plant operators be properly registered as legitimate private power plant operators, to ensure compliance with electrical safety and environmental standards and thereby providing a data base that can be used for both planning and as a source of emergency power when required.

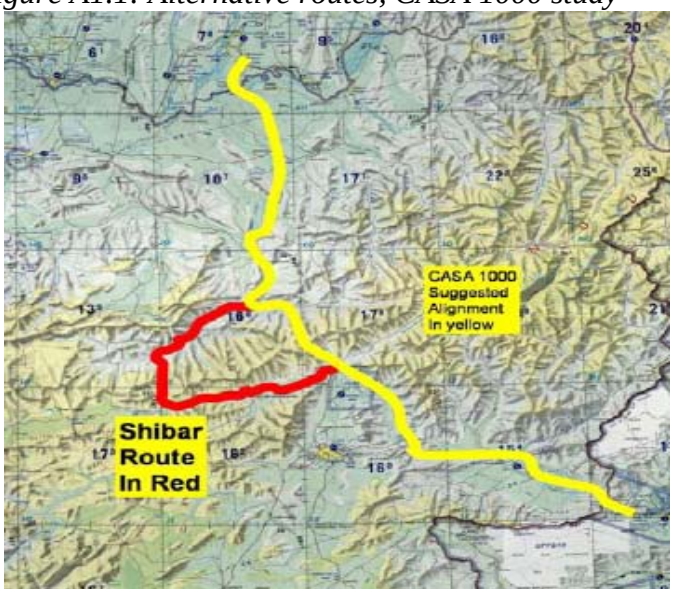
Annex I: Opportunity costs

136. Afghanistan is a mountainous country, and the major routes of its transportation and power transmission infrastructure are said to be highly constrained. Opportunity costs may therefore arise when the construction of a particular power transmission line in a given corridor *forecloses* use of the same corridor for *other* uses, thereby imposing additional costs on that other use. For example, if the available right-of-way for power transmission excludes use of the same right of way for the proposed north-south rail line, then the cost of the transmission line should include the incremental cost of rerouting the rail line to its next best alternative; and vice-versa for the rail line plan. Phrased differently, were both rail and power options considered simultaneously, one would choose that alternative which minimises the NPV of both sectors combined.

Salang Pass constraints

137. The Salang Pass, to the North of Kabul, is one such corridor that is frequently cited as a bottleneck, and some reports claim that there is insufficient space for more than one run of major transmission. The CASA-1000 and UAP studies both identify the pass as the best north-south power transmission route; the next best option for HVDC power transmission would be rerouting across the Ghorband Valley-Shibar Pass-Shekari valley (Figure A1.1), an option estimated to cost an additional $50 million.

Figure A1.1: Alternative routes, CASA 1000 study



138. The CASA-1000 study notes that there is a 7 km segment of the Salang Pass route where the available rights-of-way are constrained by the existing 2x220kV line, for which the report notes a number of options:

- Relocate the existing 220 kV line closer to the mountain on steel tubular poles with insulated arms and shorter spans to limit the conductor swing; and route

the proposed HVDC line on steel tubular poles as well but closer to the tunnel, an option costing an additional $4.2million.[57]

- If relocating the 220 kV line does not provide adequate corridor to place towers for the HVDC line, the spans can be shortened to limit the conductor swing and hence narrow the required minimum right-of-way for the proposed line. In this option, lattice steel towers with narrow foot print could also be utilized for the HVDC line.
- In case the existing corridor is too narrow at some places and the above two options cannot be employed, then converting a portion of the existing 220 kV line to underground cables can be considered[58]. This will allow the existing 220 kV rights-of-way (RoW) to be used for the proposed HVDC line. The incremental cost is estimated at $28million.

139. In other words, the cost of the CASA1000 line across the Salang Pass is between $4.2million and $28million greater than in the *absence* of the existing 2 x 220kV line. But these are *not* opportunity costs – but simply costs that are part of the cost of building the CASA-1000 line.

140. There is some uncertainty about these conclusions. FS update (dated February 2011) is described as a "desk study" based on satellite imagery, and merely updates the earlier FS. That original study is based on the July 2008 Draft Phase 2 report, whose transmission routing studies are based on 1:50,000 maps plus an "inspection on the ground for almost the complete length" from Sandtuda to Peshawar. Whether the study team actually *walked* the 7km segment where these serious RoW limitations are identified is not stated.

141. The terrain is undoubtedly difficult for power transmission, both for construction and for operational maintenance. In winter, the road seems vulnerable to avalanches,[59] notwithstanding the presence of avalanche galleries on some sections. There is a 2-mile road tunnel section near the summit, but this carries traffic far exceeding its design capacity, and is frequently blocked by accidents and

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57 The report estimates the cost for converting 7 km of 220 kV double circuit line as tubular pole line having reduced average span of 275 m at US$ 600,000 per km, and notes that the existing conductors and some other material can be re-used and the salvaged lattice steel towers can be bundled and transported to a store yard for future use as spare towers.

58 The report states that in this case, surge arresters and terminal structures will be required on both ends of the underground cable section. The required length of the existing overhead line which would be needed to be converted to underground cable can only be determined after a detailed survey by a qualified overhead line surveying company. Approximately 7 km of the existing 220 kV double circuit line is envisaged to be undergrounded in order to use the existing 220 kV line RoW for the proposed HVDC line. The budget estimate for the required cable is US$ 2 million per kilometer, including the terminal equipment.

59 In 2010 an avalanche on the Pass reportedly killed 165 people (New York Times, 10 February 2010: *"Heavy winds and rain set off 17 avalanches that buried more than two miles of highway at a high-altitude pass in the Hindu Kush mountain range, entombing hundreds of cars and cutting off Kabul's heavily travelled link to northern Afghanistan, officials said Tuesday."*).

breakdowns.[60] Nevertheless, for most of the route across the Salang Pass there appears to be adequate space for additional transmission lines (Figure A1.2). Our own analysis, based on photographs and Google Earth surveys, is that we see no insurmountable problems with constructing two or more lines across the col above the Salang pass – though as discussed in the main report, there are many reasons for *not* putting all of the North-South transmission lines into the same corridor.

Figure A1.2: Salang Pass in Winter

Potential conflicts with CASA-1000

142. The CASA 1000 project and other HVDC import variants have high uncertainty, particularly as to timing, and prudent planning for Afghanistan suggests its power sector development plan be formulated under the baseline assumption that it will *not* be implemented. If the projects do at some point move to implementation, one may then assess its incremental costs and benefits associated with adjusting the chosen path. The corollary of this assumption is that if indeed there were potential conflicts over the Salang Pass, any incremental costs for rerouting, under-grounding or reconfiguration of existing or planned lines would then need to be balanced against the incremental *benefits* to Afghanistan – although we are of the view that even if CASA-1000 were faced with two 2x220kV lines in the Salang Pass, we see no reason why that could not be accommodated (at relatively small incremental costs).

143. Moreover, an HVDC line has a much simpler low profile, and heavy duty, double-conductor construction is less prone to icing and wind loadings. Unlike 220kV, it is difficult and costly to interconnect HVDC with loads or generation en route. Consequently there is a much stronger rationale for using the Salang Pass route as the shortest route to Kabul and thence to Pakistan, than for the additional 2 x 220kV line presently contemplated.

[60] USAID has just issued (1 June 2012) a work plan for examination of options for the Salang Pass tunnel, including rehabilitation of the existing tunnel, a new, lower level tunnel, and the possibility of an alternative route without a tunnel.

Potential Conflicts with proposed rail lines

144. There does not appear to be any conflict between power transmission and rail in the Salang Pass, because a rail route across the pass does not appear to be technically feasible, since the allowable gradients cannot be met without major sections of rail tunnel. All of the rail routes from Kabul to the north (sighted to date) utilise the Ghorband Valley-Shekari Valley route that bypasses the Salang Pass (see Figure A1.3 and A1.4).

145. The rail gradients shown in Figure 2.3 show one or two sections in excess of 3%. Typical maximum gradients are between 2%-3% (Iran UIC 2.8%; ARR-AREMA[61] 2%).[62] Sections of the Khyber Pass railway (Jalalabad-Peshawar) has a ruling grade of 3% with some reversing sections, and a 4% grade between Landi Khana and Landi Kotal, "*albeit downhill in the loaded direction*"[63]. Whether tunnels would in fact be needed for this railway route is (presumably) addressed in the MJAM rail feasibility study currently underway.

Figure A1.3: Proposed rail corridor gradients

146. Transmission tower plotting normally takes advantage of hilly sites so that spans can be increased as much as possible to reduce construction costs. In Afghanistan spans will range from a typically 350m on flat terrain up to 1km (or more in special cases) across valleys. Thus transmission line alignments are unlikely to be suited to rail alignments although their proximity (within a 1km or so of each other) will reduce the cost of tower, foundations and conductor supply and access. Where necessary

61 AREMA=American Railway Engineering and Maintenance-of-way Association; AAR=Association of American Railways, UIC= International Union of Railways

62 H. Klein: *Afghanistan Resource Growth Corridors: Rail Issues for Kabul Discussion*, March 2012.

63 *Preliminary Policy Note: Development of Railways in Afghanistan* (Undated, R. Bullock, World Bank)

transmission line contractors usually build short access roads off rail or road routes for access to their optimum tower sites.

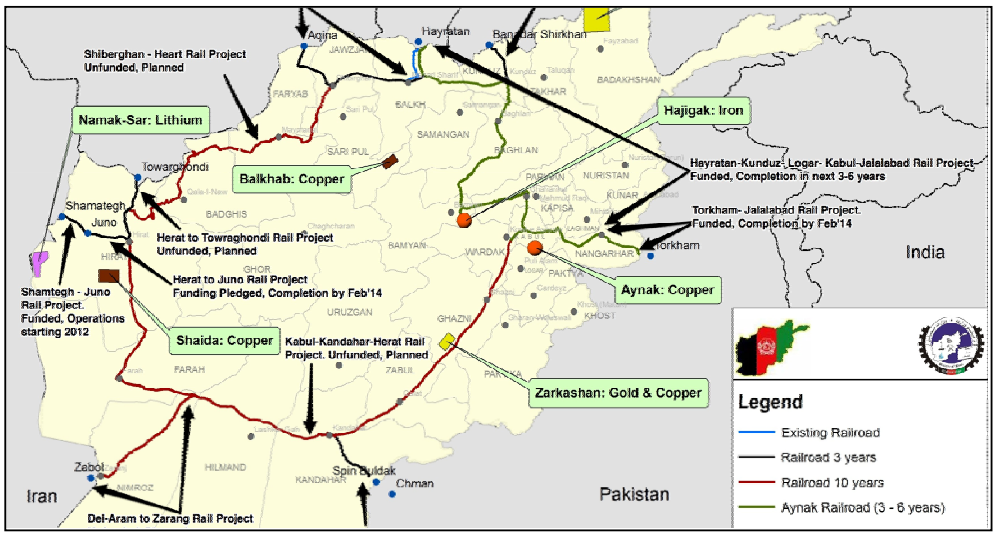
147. In short, there are no opportunity costs imposed on railways associated with transmission line planning along the Salang Pass route. There may well be good reasons why an optimal transmission plan would not wish to place all North-south lines in the same corridor – security and reliability reasons may dictate that (for example) the additional 2 x220kV line would be across a different route. Moreover, such an alternative routing would also spur development spur developments along the proposed rail-road corridors

148. Phrased differently, while transmission line planning should certainly take into account the location of power demands in the resource corridor, and of potential power plant locations (such as the proposed 400MW coal project to be developed by MJAM), the *routes* chosen for *transmission* lines have no impact on planning the routes for new railroad lines.

Railway Electrification

149. A more difficult question concerns the possible connection between railway *electrification* and the configuration of the transmission network.[64] However, none of the railway policy documents for Afghanistan sighted thus far discuss electrification,[65] except in some cases to simply state that traffic is insufficient to justify electrification. Presumably electrification is also a subject taken up in the MJAM Aynak Railway feasibility study currently underway: for the moment we may assume that diesel traction would be used.

Figure A1.4: Railroad plans for Afghanistan



64 For example, the completely electrified Swiss railway system owns 6 hydropower stations, and its *own* power transmission network of some 1,700 km.

65 see e.g., Klein *op cit.*, or *Preliminary Policy Note*, *op.cit.* or ADB, Railway Development Study, March 2009.

Constraints on the Shibar Pass route

150. The Shibar pass route was the original link and main between Kabul and the North before the Salang Pass tunnel was completed in 1964. Given that the maximum rail gradient here is 4% and more suitable for a rail connection, and from pictures available on the web, it would seem that the terrain is less constraining than the Salang Pass route (Figure A1.5). Until the rail feasibility study is completed it is impossible to identify specific potential conflicts with a transmission line route: for which, again, one would need to make a ground level reconnaissance.

Figure A1.5: Shibar Pass Route

Conclusions

151. In general it is unlikely that rail planning will present any particular constraint on transmission planning. Moreover for an existing line if one or more towers presents an obstacle to a subsequent rail alignment, it is a relatively easy matter to reposition them without any significant disruption to power supplies. The planning of transmission line alignments (discussed in Section 4) can proceed without fear of significant opportunity costs implied by competing rail or road requirements in the resource corridor.

Annex II: Revised Electrical Design Standards for Kabul

Table 1: Climatic and Geographic conditions for Kabul Power System		
Altitude	1,700 – 2,100 metre a.m.s.l (Altitude correction factor = 1.12-1.18)	
Dry period	June to November	
Rainy period	December to May	
Annual rainfall	327 mm	
Air temperatures	Warmest month (°C)	Coldest month (°C)
	+ 25°C average; + 35°C noon;+18°C night	-3°C average;+2°C noon; -8°C - night
Air humidity	Average summer	Average winter
	35%	75%
Soil thermal resistivity	Average	Maximum
	+1.2 °C m/W	+3.0 °C m/W
Maximum solar radiation	1,200 W/m²	
Wind	Maximum wind velocity	Wind and dust conditions
	25 m/s	Sand and dust storms in summer
Keraunic level	23	

Table 2: Revised Electrical Design Standards for Kabul Power System[1]					
Parameter	**220 kV system**	**110 kV system**	**(15)20 kV system**		**0.4 kV system**
Nominal voltage Un	220 kV	110 kV	20 kV		400 V (230V phase-n)
Highest system voltage Umax	245 kV	123 kV	24 kV		-
Design voltage Um	245 kV	123 kV	24 kV		1 kV (0.6 kV phase-n)
Voltage variation	-	-	-		+/- 7.5 %
Standard frequency	50 Hz				
Rated short time current (3s)	40 kA	31.5 kA	20 kA (grid substations) 16-20kA (junction substations)		12.5 kA
System configuration	3 phases, 3 wires				3 phases, 4 wires ; 1 phase, 2 or 3 wires
Earthing	Solidly earthed	Solidly earthed	Earthed through auxiliary transformer Zy (15)20kV/0.4kV		Solidly earthed
Insulation coordination	IEC 60071-1				-
Rated impulse withstand (peak)	1,050 kV	650 kV	125 kV		-
Rated 1mn power frequency withstand (peak)	460 kV	275 kV	50 kV		-
Minimum phase-to-earth air clearance	2,100 mm	1,300 mm	270 mm		-
Creepage distance outdoor	25 mm/kV	25 mm/kV	25 mm/kV		-
Transformers	**220/110 kV**	**110/20 kV**	**(15)20/0.4 kV**		-
			Distribution	**Substation auxiliary**	
Vector group	YNyn0	YNd5	Dyn5	Zy1	-
Rated power (with tolerance of ± 10%)	100 MVA	40 MVA	-	400 kVA	-
Impedance (with tolerance of ± 7.5%)	15.5%	14.9%	4.3 to 5.0%*	4.0%	-
Tap changer	On load, ± 10%, 19 positions	On load, ± 16%, 19 positions	Off load, ± 5%, 5 positions	Off load, ± 5%, 5 positions	-
OHL Conductors	**ACSR300**	**ACSR185**	**ACSR185**		**-**

Annex III: Procedure for Synchronisation with CAS Countries

In their Master Plan Inception Report Fichtner proposed a road map for an Application to Connect Afghanistan with CAPS summarized as follows:

Step 1: Intergovernmental Agreement

The Coordination Electric Power Council of Central Asia (CA CEPC) was established on the basis of the intergovernmental agreement of June 1999 with the participation of Uzbekistan, Kazakhstan, Kyrgyzstan, and Tajikistan. Therefore, the governments of the four Central Asian countries have to be informed by the government of Afghanistan (MEW) that Afghanistan would like to be connected to CAPS.

Step 2: Involvement of the Coordination Electric Power Council of the Central Asia (CA CEPC).

The governments of the four Central Asian countries will inform the government of Afghanistan to contact the Coordination Electric Power Council of Central Asia (CA CEPC) and will also inform CA CEPC work together with DABS - on a connection agreement.

Step 3: Involvement of CDC Energy and JSC Sredazenenergosetproekt

It is expected that CA CEPC will inform DABS regarding the further steps to reach an agreement on the interconnection with CAPS. CA CEPC will inform CDC Energy / Tashkent to carry out the necessary analyses. Also, the services of JSC Sredazenenergosetproekt have to be commissioned to determine the amount and location for the installation of emergency control system equipment. At the working level, an indicative list of preparatory works and studies which have to be performed in preparation of the synchronous interconnection between Afghanistan and CAPS is given below.

Review of Existing Association Rules and Grid Codes as preparatory work for setup of Interconnection Contract

The current legislation, including national or international grid codes, should be analysed in detail as well as Association Rules with respect to membership conditions, and so on. From these documents, most of the details which shall be addressed within the resulting interconnection contract have to be extracted carefully

Preparation Studies phase

An extensive preparatory studies program is necessary in order to assess the system requirements. In the following, a brief list of studies which shall be performed as a minimum is indicated:

- Load flow calculations, short circuit calculations, transient stability calculations - special focus on inter-area oscillations
- Power system restoration principle, detailed plans
- System protection scheme, line protection scheme, generation unit protection scheme

Review of Technical Details of the Interface between the Systems

- Protection device settings, coordination
- Power and energy measurement device requirements, definition of main and backup device location
- Synchronisation scheme, procedure

Review of Required Data Exchange

Planning Data

- System development
- Hourly system congestion information, steady-state information (topology, generation and load pattern)
- Transient stability information, dynamic models, parameter
- Online Information for Common Area of Observability within SCADA Systems

System Operation Data

- Schedules for inter-area power exchange
- Energy metering device measurements
- Frequency set point
- Reactive power / voltage operation procedures schedules

Organisational Contacts & Infrastructure

- Responsibilities for scheduling, accounting, dispatching, IT infrastructure, and so on.
- IT infrastructure, network, firewall settings, back-up procedures, common points of contact, sharing of infrastructure costs

Agreements on Procedures

- Common active power control principle
- Power system restoration
- Common language
- Common staff training
- System protection
- Under frequency load shedding
- Special protection schemes
- Range of permissible voltages, frequencies
- Test procedures for compliance monitoring
- Compliance monitoring procedure

Usually the new connected system will have to pass special tests before trial parallel operation.

- Emergency plans, reporting after major events
- Monitoring of quality of power exchange on the interface, definition of specific minimum quality standards to be fulfilled

Interconnection Contract

The interconnection contract includes a detailed rights and duties description.

One of the main appendices should be the so-called “delimitation contract”, which defines

exactly the geographical limit of the new connected system and reflects the existing interfaces to other systems where the exact documentation of the corresponding substation feeder arrangement is required with detailed indication of all circuit breakers and separators which have to be mechanically dismantled and can be put in operation only after a precise procedure request/information/approval from the other power system operators

Annex IV: Scope of Proposed Project and Associated Project Costs

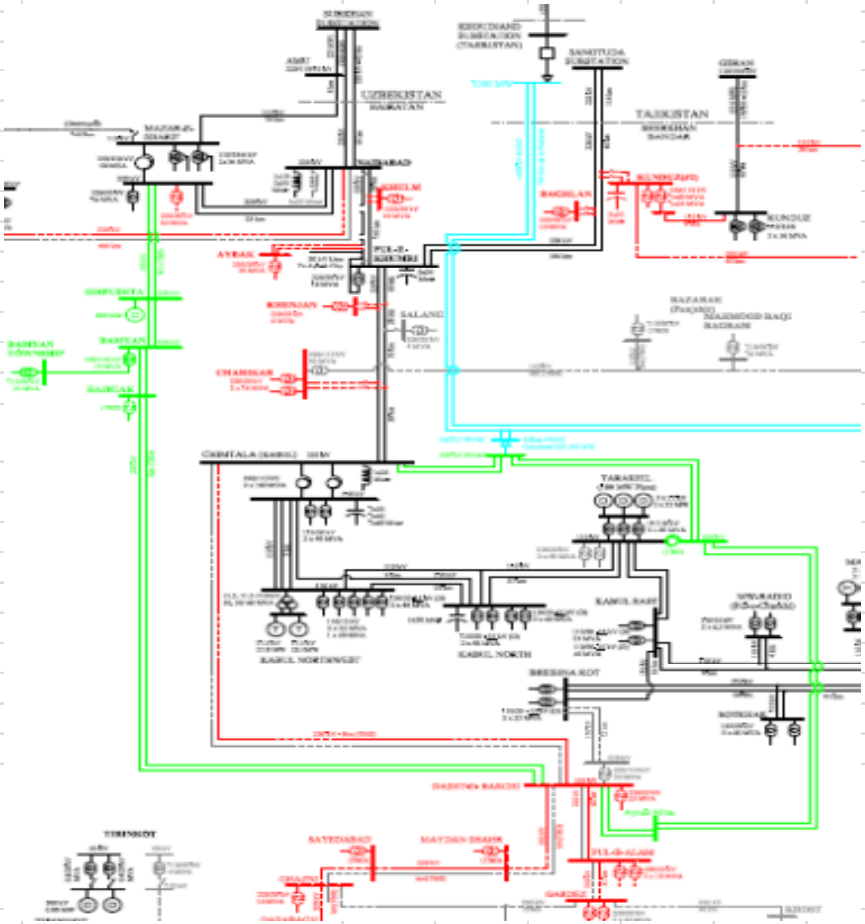
Estimated Project Cost of 220kV North-South Line to Anyak and Completion of 220kV ring around Kabul

				US$million		
A	**Tranmission Line Costs**		**dbl cct**	**220kV**	**500kV**	**Upgrade**
TL	Route Sections (k$/km)	Finance	km	204	594	390
1	MazarSharif to Dari Sauf (future)	TBD	143	29.2	84.9	55.7
2	Dari Sauf to 400MW Ishpushta	TBD	119	24.3	70.7	46.4
3	Ishpushta to Bamyan 220/110kV	MCC	45	9.2	26.7	17.5
4	Bamyan to HajiGak (future)	MCC	45	9.2	26.7	17.5
5	HajiGak to Dasht-e-Barchi Substation	MCC	125	25.5	74.3	48.7
6	Dasht-e-Barchi to Aynak Copper	MCC	22	4.5		
7	Tarakhail to Aynak Copper	MCC	56	11.4		
8	Tarakhil to Chamtala (via future CASA HVDC)	TBD	20	4.1		
9	Chimtala to Dashte Barche	ADB	29	5.9		
	Total 220kV Lines		**604.0**	**123.3**	**283.3**	**186.0**

B	220kV Substation Costs	Bays	MVA	SWg P&C	Others	Land & bldgs	**Total**
SS	Unit Rates based on ICB (k$/unit)	332	37	205	167	79	**US$m**
i	Mazar-e-Shariff (2 new bays)	2		2	2		1.4
ii	Ishpushata (excludes Generator Tranfo & Bays)	5		5	5	0.5	3.6
iii	Bamyan 220/110kV & 15MV transformer	8	15	7	7	1	5.9
iv	Dasht-e-Barchi Substation 220kV extensions	4		4	2		2.5
v	Anyak 220/110/20kV & 2*50MVA trafos	7	100	7	7	1	8.7
vi	Tarakhil 220kV extensions	4	100	4	4	1	6.6
vii	Chimtala 220kV extensions	2		2	1		1.2
	Total 8 220kV susbtation costs	**32**	**215**	**31**	**28**	**3.5**	**30.0**

	Finanacing Requirements for North South Line and Kabul 220kV ring	Finance source	Item in Annex x	TL dbl cct route km	Build TL 220kV US$	Build for 500kV T&S US$m	500kV TL for 220kV ops US$m
TL	Mazar-e-Sharif to Ishpushta	TBD	1,2	262	53.5	155.6	102.1
SS	Mazar-e-Shariff 220kV Substn extn	TBD	i		1.4	21.4	
TL	Ishpushta-Bamyan-DashteBachi-Anyak-Tarakhil	MCC	34567	293	59.8	127.7	83.8
SS	Ishpushta-Bamyan-DashteBachi-Anyak-Tarakhil	MCC	ii iii iv v		27.3	81.9	
TL	Chimtala-Dasht-e-Bachi; Chamtala-Tarakhil	ADB/tbd	89	49	10.0		
SS	Chimtala and Tarakhil 220kV extensions	CASA	vi vii		1.2		
	Subtotal MCC Costs			**293**	**87.1**		
	Project Base Costs			**604**	**153.3**	**386.6**	**186.0**
	Project Costs with contingencies	20%			**183.9**	**464.0**	**223.1**

Scope of RCD Project Shown in Green - HVDC Cas project shown in Blue



Project Staging	US$m
Tarakhil to Anyak	32.2
Ishpustra to Anyak	72.4
Mazar-e-Sharif to Ishpusta	65.9
Tarakhil to Chimtala	13.5
Total Project	183.9