ADB

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May 2013

Islamic Republic of Afghanistan: Power Sector Master Plan

(Financed by the Japan Fund for Poverty Reduction)

Prepared by FICHTNER GmbH & Co. KG

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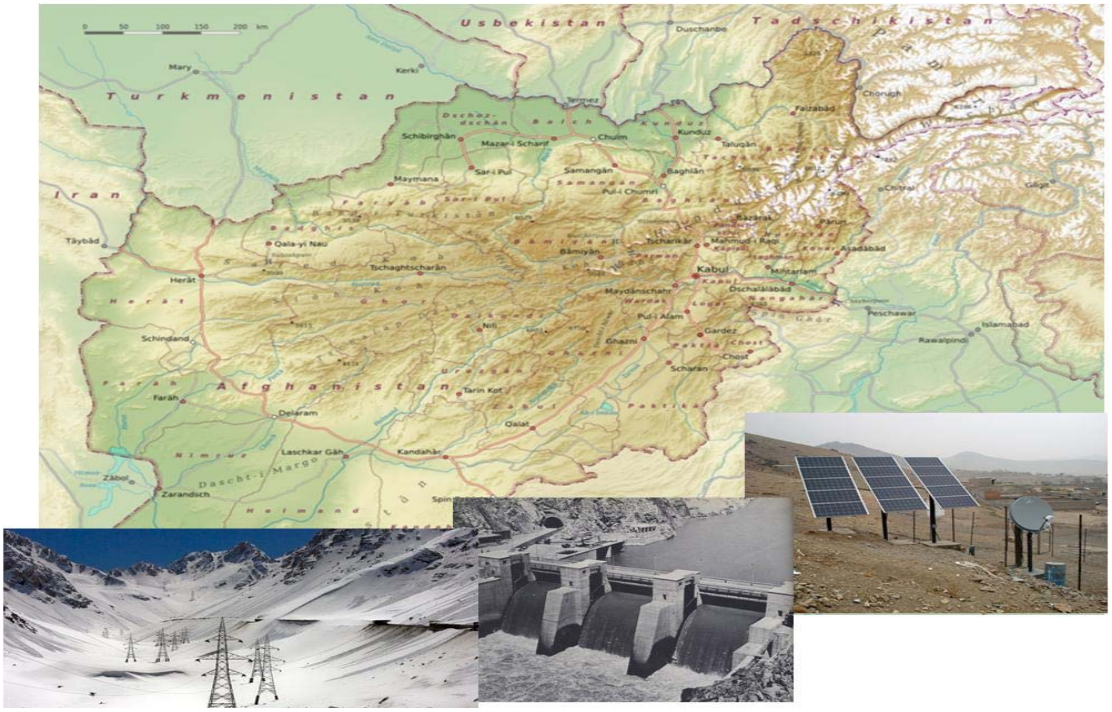
Asian Development Bank

Islamic Republic of Afghanistan
Ministry of Energy and Water



Power Sector Master Plan

Final Report

April 2013

ASIAN DEVELOPMENT BANK
TA 7637 (AFG) Power Sector Master Plan

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1. Executive Summary

The scope of the Power Sector Master Plan for Afghanistan was to identify the priorities, time frame and costs associated with power sector development goals. The present report includes the results of work performed for development of Power Sector Master Plan and includes also the comments received from the Ministry, DABS and the Donors. Furthermore the report is aimed to be and it forms the basis for discussion during presentation to the Ministry of Energy and Water in April 2013.

For development of Power Sector Master Plan, the review of the existing planning documents were carried out and a set of supply options and major transmission projects needed for covering the Afghan demand were identified. Environmental impact and the social safeguard implications of the major generation and transmission project were discussed and an optimized expansion plan was conducted to cover the demand growth expected for Afghanistan.

Power system studies were carried out to identify necessary network expansion within the transmission network and to justify expansions in the transmission network required in the provinces to extend the coverage area of the power supply.

The strategic goal of the Afghan power sector is to provide power supply to the population in whole Afghanistan. Currently 28 % of the Afghan households are connected to power supply systems. The connecting rate within the provinces differs in wide range from zero in rural area to near 100% in urban regions.

Furthermore Afghan government pointed out the wishes of the development towards more self sufficient power supply and towards the establishment of an integrated network for Afghanistan.

Based on the optimized generation expansion plan and the expected demand development within the provinces, a development in stages of the power system together with the expected financial requirement was established. The cost estimation for the project stages was carried out on basis of unit costs and the accuracy of the cost estimate meets the requirements of the project definition phase of the master plan.

Time horizon for this Power Sector Master Plan is twenty years up to 2032 and the connection rate in rural area will reach 65 % of the households. For urban areas the high level of near 100 % will be reached.

The development for the different projects was structured in stages. Stage A comprise the short term up to 2015 and stage B covers the development up to 2020. Long term development is considered in stage C up to 2025 and stage D up to 2032.

Major projects with immediate need for implementation are identified. These projects are

- development of Sheberghan TPP with 200 MW
- finalizing Salma HPP and Kajaki Expansion HPP

- new Turkmenistan to Afghanistan interconnector stage A
- Hindu Kush crossing stage A
- new Turkmenistan to Afghanistan interconnector stage B
- NEPS to SEPS interconnector stage A
- investment within the provinces stage A

and the list is confirming the measures and projects already under implementation process.

To achieve the goal of providing power supply for whole Afghanistan, a large investment effort for all the subareas generation expansion, transmission reinforcement and development has to be taken. This will need a total investment of $10,096m, $7,330m for generation development and network integration, $1,727m for major transmission projects and $1,040m for transmission network development within the provinces up to the year 2032.

The total investment for stage A is estimated at $1,213m. Stage B will require $1,465m while stage C and stage D will require about $1.410m and $6.010m. The high investment in Stage D is related to the hydropower plants.

Overview on Investment type	Investment optimized scenario [m$]				
	Subtotal by project	Stage A	Stage B	Stage C	Stage D
Generation development	7329.6	327.6	348.5	981.5	5671.9
Major transmission projects	1726.8	595.0	676.9	212.9	242.0
Transmission development within the provinces	1040.1	290.1	439.8	215.1	95.0
Total	10096.4	1212.7	1465.2	1409.5	6009.0

Investment by stages and investment type for the optimized scenario

To cover expected load growth is a challenge for the network development. Therefore, if the planning criteria normally applied in mature power systems (like n-1 security) would be considered in the future, additional high investment in the transmission system will be needed.

A demand forecast within 20 year project horizon has been prepared based on commonly applied methodology. Inputs are key socio-economic variables, such as GDP growth, as well as developments of the average tariff level and household connection rates, as critical deciding factors. Starting with the forecasts for the various provinces, the anticipated total demand forecast for Afghanistan has been estimated.

For the whole of Afghanistan, gross demand, i.e. dispatched electrical energy, will increase in the base case scenario by 5.7% or 8.7% per annum on average from its current level to 18,400 GWh in 2032. Total peak demand in 2032 is expected to stand at around 3500 MW. In addition, high and low scenarios were developed which show a total gross demand of about 22,500 GWh and a peak of 4300 MW in 2032 in the high scenario and around 13,700 GWh gross demand and 2600 MW peak in the low scenario.

The general methodology and data basis used for demand forecast as well as the results achieved have been discussed intensively during the meetings held for the different phase of the project. The conclusion at the end of the discussion was that the result of the demand forecast is based on proven methodology and gives the best estimation possible for the uncertainties in general in that matter and especially for Afghanistan situation.

Based on a review of existing generation and transmission assets together with the generation and transmission expansion plans, the transmission network model for the existing system and the power system optimization model have been set up. Options for additional generation capacity and transmission system development have been identified.

To cover demand growth in the most economic way, the local resources of power generation as well as the import of power from neighboring countries have to be considered. The optimization process identified robust solution for generation expansion and expansion of transmission capacity for imports.

Thermal generation at Sheberghan gas fired power plant with 200 MW capacity is chosen in the optimization process as first power plant to be constructed with additional capacity of 200 MW in a second stage.
Import from Turkmenistan thermal power plants is required to balance winter deficit in hydro based generation. The capacity of 1000 MW for the new Turkmenistan to Afghanistan interconnector is required as early as possible as well as the additional Hindu Kush crossing and the NEPS to SEPS interconnector.

For the additional Hindu Kush crossing it is recommended to use the so called Bamyan route for a new transmission line on 500 kV level. The Bamyan route will avoid the narrow space and difficulties along the Salang Pass, will allow connecting further generation by coal fired power plants along the route and will secure power supply of Kabul and south Afghanistan by using a separate route.

For the development in later stage the hydro generation Kunar A and B and Kajaki Addition are recommended by the optimization process as well as the coal fired power plants for the mining projects Aynak and Hajigak along the Bamyan route.

Kabul is currently facing the problem of power shortage and the government emphasized that immediate increase of transmission capacity towards Kabul and further on to south is on high priority. Choosing the Salang Pass route for construction of the new line to Kabul may have the advantage of slightly shorter time for construction and will have slightly less investment costs, as an separate investigation on technical feasibility of this route has shown.
From the other point of view, significant disadvantages need to be considered.
First, the network integration of the coal fired power plants along the Bamyan route and the power supply of Bamyan region will require an additional transmission line and the additional investment will be significant high, adding to the total investment.
The Salang Pass will also be the route for the HVDC line for CASA-1000 project, as the actual planning of CASA-1000 project indicates and the construction of a third line along the Salang Pass will be very difficult, if not impossible.

Routing all lines to Kabul on one corridor will increase the risk of losing the whole supply for Kabul region due to one single event, with it's major consequences.

It has to be pointed out that in the case of the stressed that the recommendation from the master plan point of view for choosing the Salang Pass for the additional Hindu Kush crossing is for the Bamyan route, in order to avoid the disadvantages have to be taken into account which may imply significant additional costs that would occur if the Salang Pass route is chosen.

The Master Plan has developed also a road map for creation of a national Afghan power system. In this respect, the order of connecting the province to the national power system of Afghanistan is different. For seventeen provinces network connection or network expansion will be possible and necessary from the demand point of view in the first development stage. These provinces are Badakhshan, Baghlan, Balkh, Faryab, Helmand, Herat, Jowzjan, Kabul, Kandahar, Kunduz, Laghman, Nangarhar, Parwan, Samangan Sar-e Pol Takhar and Wardak. For thirteen provinces as Badghis, Bamyan, Ghazni, Ghor, Kapisa, Khost, Kunar, Logar, Paktia, Paktika Panjshir, Uruzgan and Zabul network connection will be possible and necessary in the second development stage. For the remaining four provinces network connection is expected at a later point of time as for Daykundi a connection to the network is not economically justified. For Nimruz currently the power supply is ensured to near 100 % from Iran's power system and the distance to the Afghan network is too long to justify an interconnection. Nuristan, Daykundi and Fayab province are not densely populated and decentralized power supply solutions are recommended for these provinces.

With the proposed development according to the optimized scenario it will be possible to serve the demand growth and the average share of households targeted. Access to power supply will reach 83%. For this scenario the share of local generated power will grow almost continuously up to 67% of total consumption.

Year	Generation expansion project optimized scenario [m$]	Major transmission project [m$]	Network expansion forsupply within the Provinces [m$]	Energy sent out [GWh]	Households connected [%]	Share of local generation [%]
2013	164	0	10	4507	39	45
2014	164	177	92	5054	44	44
2015	87	209	138	5666	50	43
2016	87	150	151	6370	56	40
2017	178	154	95	7153	61	44
2018	438	193	123	7769	64	39
2019	438	195	81	8406	66	38
2020	438	195	26	9087	69	43

Year	Generation expansion project optimized scenario [m$]	Major transmission project [m$]	Network expansion forsupply within the Provinces [m$]	Energy sent out [GWh]	Households connected [%]	Share of local generation [%]
2021	438	13	34	9636	70	45
2022	803	45	55	10339	72	54
2023	778	40	66	11047	73	52
2024	688	57	56	11720	74	74
2025	791	57	18	12439	76	73
2026	632	29	15	13157	77	73
2027	480	29	19	13933	78	72
2028	417	7	18	14740	79	71
2029	102	25	27	15586	80	67
2030	102	59	9	16478	81	66
2031	102	59	8	17418	82	65
2032	0	33	0	18409	83	67
Total	7330	1727	1040			

Details on investment, served demand and share of local generation for the optimized scenario over the planning horizon

The result of the economic optimization shows that Afghan generation resources will be committed in the second part of the investment time horizon. The availability and exploration of the coal mine for coal fired power plants usage have a high level of uncertainty. The same applies for the implementation of large hydro power plants. For security reasons and the assessment of MEW and DABS on the practicability, for some preferred projects an optimistic scenario was developed.

This scenario reflects the wish of development towards more power supply from own resources and it considers an early commissioning of a coal fired power plant at Bamyan and the two hydro power plants Sarobi 2 HPP and Kajaki Addition HPP. From the power system point of view a coal fired power plant will help a lot to overcome the winter shortage on power generation from the hydro power plants.

The investment required for generation development will be slightly higher for this optimistic scenario as shown in the following table as well as the cost for power delivered to the consumer.

Overview on Investment type	Investment optimistic scenario [m$]				
	Subtotal by project	Stage A	Stage B	Stage C	Stage D
Generation development	7618.1	327.6	2486.2		4804.3
Major transmission projects	1726.8	595.0	676.9	212.9	242.0
Transmission development within the provinces	1040.1	290.1	439.8	215.1	95.0
Total	10384.9	1212.7	3602.9	428.0	5141.3

Investment plan segregated by stages and sectors for the optimistic scenario

Due to the early commissioning of local generation units, the share of local generation on total consumption will increase to 61% in 2020. On the long run up to the end of the planning horizon the share of local generation will be 68% which is nearly the same as for the optimized scenario

Year	Generation expansion project optimistic scenario [m$]	Major transmission project [m$]	Network expansion forsupply within the Provinces [m$]	Energy sent out [GWh]	Households connected [%]	Share of local generation [%]
2013	164	0	10	4507	39	45
2014	335	177	92	5054	44	44
2015	463	209	138	5666	50	43
2016	463	150	151	6370	56	40
2017	463	154	95	7153	61	44
2018	463	193	123	7769	64	39
2019	724	195	81	8406	66	38
2020	261	195	26	9087	69	61
2021	261	13	34	9636	70	60
2022	473	45	55	10339	72	53
2023	473	40	66	11047	73	51
2024	563	57	56	11720	74	49
2025	666	57	18	12439	76	47
2026	666	29	15	13157	77	46
2027	443	29	19	13933	78	70
2028	443	7	18	14740	79	69
2029	128	25	27	15586	80	65
2030	128	59	9	16478	81	64
2031	38	59	8	17418	82	68
2032	0	33	0	18409	83	68
Total	7618	1727	1040			

Details on investment, served demand and share of local generation for the optimistic scenario over the planning horizon

A further recommendation is It is recommended to carry out the feasibility studies or update the feasibility studies for several projects which have been included in the investment plan, in order to have a more detailed picture on the own generation resources in Afghanistan. This was not possible to be done in the framework of this master plan and the presented results are based on the available data supplied by MEW and DABS through the time period of elaboration of this study.

In general, an update of Power Sector Master Plan has to be carried out on regular basis every three to five years. For Afghanistan situation, on development of infrastructure and economy are high. Input data for demand forecast and the power sector master plan are subject to continuous change and an update will be required to take into account the future development.

2. Introduction / Project Description

2.1 Authorization

The

ASIAN DEVELOPMENT BANK
6 ADB Avenue
Mandaluyong City 1550
Metro Manila, Philippines

appointed

FICHTNER GmbH Co. KG
Sarweystrasse 3
70191 Stuttgart
Germany

to perform consultancy services for

TA-7637 (AFG) Power Sector Master Plan

2.2 Scope of Services

Under the Terms of Reference, the Consultant's scope of work was defined as follows:

(i) Update Master Plan from 2004
(ii) Demand Forecast
(iii) Development Generation Plan
(iv) Development Transmission Plan
(v) Study of Constraints of Salang Pass / Alternative Bamyan Route
(vi) Analysis of Connecting NEPS and SEPS
(vii) Assessment of Power Purchase Agreements
(viii) Source Document for Long-Term Development Planning
(ix) Capacity Building for Updating the Master Plan
(x) Models for Afghanistan Power System
(xi) Coordinate with Central Asian Regional Power Sector Master Plan

2.3 Involved Parties

In addition to the contract partners Asian Development Bank and Fichtner, the Government of the Islamic Republic of Afghanistan through its Ministry for Energy and Water (MEW) and Da Afghanistan Breshna Sherkut (DABS) are participating in the project.

2.4 Consultant's Workforce

The project organization for performing the services under technical assistance TA-7637 (AFG) Power Sector Master Plan was structured to meet the requirements of the extensive and complex tasks.
As shown in the following chart, the project is coordinated by the Project Executing Agency ADB, represented by Jim Liston, the Ministry of Energy and Water, and Da Afghanistan Breshna Sherkut of the Islamic Republic of Afghanistan.

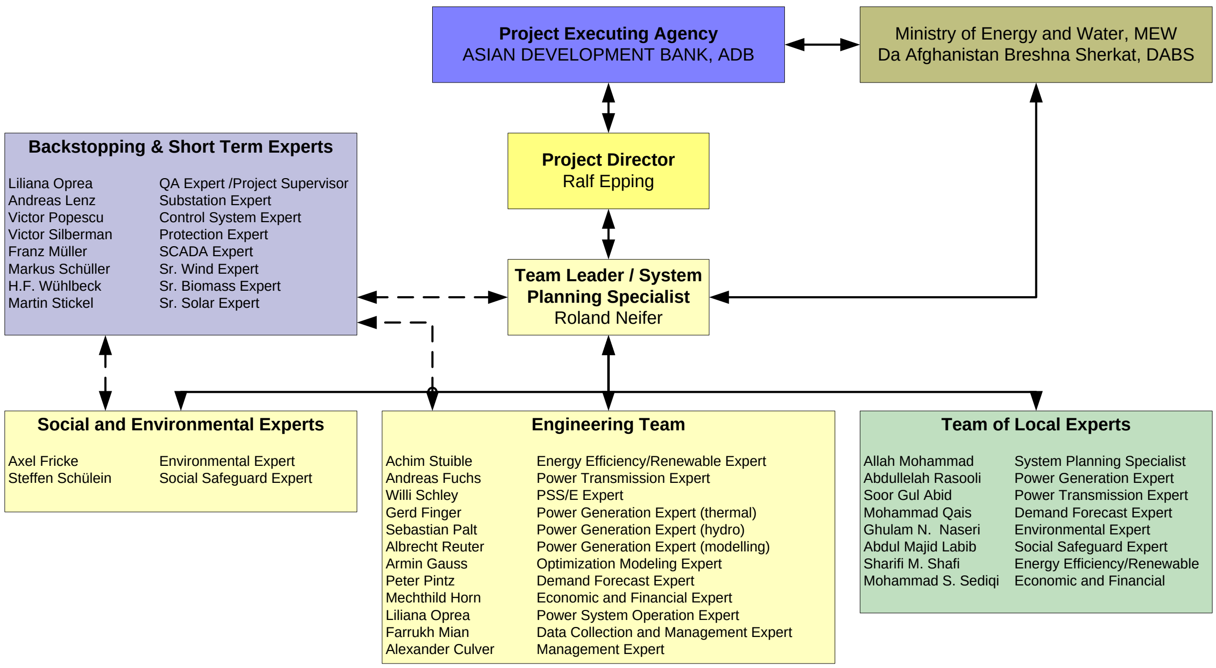


Figure 2.4.1-1: Project organization chart

The consultancy part of the organization consists of the Project Director, the Team Leader and the team of national and international experts supported by Backstopping and Short Term Experts as required.

2.4.1 International consultants

As international consultants, the following experts are involved in the project:

- Ralf Epping Project Director / Executive Director
- Roland Neifer Team Leader / System Planning Expert
- Achim Stuible Energy Efficiency / Renewables Expert
- Andreas Fuchs Power Transmission Expert
- Willi Schley PSS/E Expert
- Gerd Finger Power Generation Expert (Thermal)
- Sebastian Palt Power Generation Expert (Hydro)
- Albrecht Reuter Power Generation Expert (Modeling)
- Peter Pintz Demand Forecast Expert

- Mechthild Horn Economic and Financial Expert
- Axel Fricke Environmental Expert
- Steffen Schülein Social Safeguard Expert
- Farrukh Mian Data Collection and Management Expert

2.4.2 National experts

For supporting the activities within Afghanistan a team of national experts was formed. The national experts are listed below, stating their fields of expertise.

- Allah Mohammad System Planning Specialist
- Abdullelah Rasooli Power Generation Expert
- Soor Gul Abid Power Transmission Expert
- Mohammad Qais Demand Forecast Expert
- Ghulam N. Naseri Environmental Expert
- Abdul Majid Labib Social Safeguard Expert
- Sharifi M. Shafi Energy Efficiency/Renewable
- Mohammad S. Sediqi Economic and Financial

2.5 Objective of Draft Final Report

This report includes all parts required and prepared for the Power Sector Master Plan as demand forecasts on province level, descriptions of identified power generation options and possible transmission expansions as well as assessments of power purchase agreements. Furthermore, the report presents the results of the study on the constraints of the Salang Pass and the desktop study for the alternative Bamyan route along the resource corridor, the description of major transmission projects, the transmission network development within the provinces and the results of the optimization process and power system study.

The report includes the comments received from the Ministries, DABS and the Donors participating on the several meetings and workshops conducted during executing the Master Plan exercise.

2.6 Acknowledgments

Fichtner's staff would like to express their gratitude and appreciation for the very valuable and close co-operation with representatives from the Ministry of Energy and Water, Islamic Republic of Afghanistan (MEW), and Da Afghanistan Breshna Sherkat (DABS) who took part in this project.

The contributions of the various agencies for local system investigations and data collection have been most valuable with discussions held in a spirit of mutual trust and at a high professional level.

2.7 General Information

2.7.1 Calendar used for the study

The Afghan official calendar is based on a solar year starting on 21 March in the Gregorian calendar.

The current year (starting 21 March 2012) is 1391, which means the Gregorian year is arrived at by adding 621 to the Afghan year and the Afghan months are as follows:

Name	Start according to Gregorian calendar	End according to Gregorian calendar	Number of days	Name used
Hamal	March 21	April 20	31	April
Saur	April 21	May 21	31	May
Jawza	May 22	June 21	31	June
Sartan	June 22	July 22	31	July
Asad	July 23	August 22	31	August
Sunbula	August 23	September 22	31	September
Miezan	September 23	October 22	30	October
Agrab	October 23	November 21	30	November
Quas	November 22	December 21	30	December
Jadi	December 22	January 20	30	January
Dalwa	January 21	February 19	30	February
Hut	February 20	March 20	29/30	March

Table 2.7.1-1: Relationship between Afghan official calendar and Gregorian calendar

In leap years, an additional day is added to the month of Hut.
The fiscal year for the Afghan Government follows the Afghan year, i.e. runs from 21 March to 20 March

For the study on the Power Sector Master Plan we follow the Gregorian calendar.

Historical data are available on the basis of the Afghan official calendar. For this data on yearly statistics, a conversion from the Afghan official calendar to the Gregorian calendar by shifting by three months is applied.

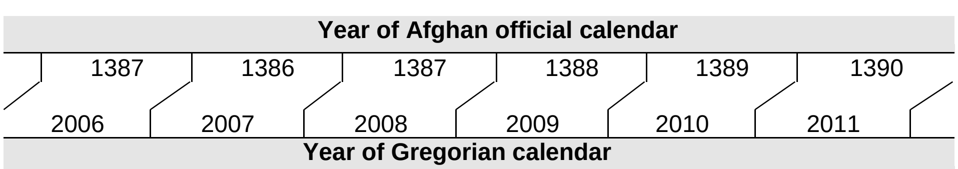


Figure 2.7.1-1: Conversion used for historical data on an annual basis

For the future, conversion is done directly without shifting. For example the year 2015 will comprise the period from Jadi 1393 to Quas 1394.

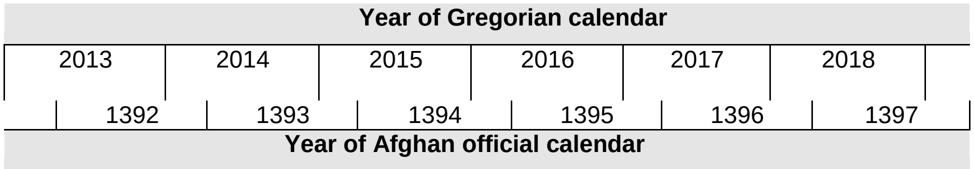


Figure 2.7.1-2: Conversion used for future data

2.7.2 Collected data and information

Data for the project were compiled at the beginning of December 2011 with the support of a team of local experts coordinated by Fichtner experts based in Fichtner's Stuttgart Home Office, and the Fichtner data collection and management expert working part time in Kabul.

Several meetings were held by the local team members – both in the presence of the data collection and management expert as well as independently – with a large number of government ministries and agencies to explain the questionnaire and to direct the questions to relevant persons and departments. The meetings that were held by the Fichtner data collection team included, but were not limited to, the following organizations:

- Ministry of Energy & Water (MEW)
- Ministry of Mines
- Ministry of Commerce
- Directorate of Environment
- Ministry of Social Affairs
- Ministry of Rural Rehabilitation and Development
- Da Afghanistan Breshna Shirkat (DABS)
- National Load Control Center (NLCC)
- Central Statistics Organization (CSO)
- AISA (Afghanistan Investment Support Agency)
- DCBA (Deh Sabz City Development Authority)

Included among the international development agencies with which meetings were held are:

- Asian Development Bank (ADB)
- World Bank
- KfW Development Bank
- United States Agency for International Development (USAID)
- United States Forces – Afghanistan

Some of the other entities with which the Fichtner teams have been actively engaged include:

- Afghan Energy Information Center (AEIC)
- Inter-Ministerial Commission for Energy (ICE)
- TETRA TECH (contractor to USAID) on power projects
- SMEC (consultant on power projects)
- KEC International Limited (a leading power projects construction contractor active in Afghanistan)
- GFA Consulting Ltd. (advisor to MEW).

The local Fichtner team members called on the various ministries and agencies to obtain the information and data as stipulated in the questionnaires that were prepared and forwarded in advance of the data collection phase.

The documents received by Fichtner via ftp server and/or e-mail from the local team members and the International Data Collection and Management Expert were stored in a library. The bibliography of this library is given in **Annex 2.7.2-1**.

For labeling the documents, a numbering system was adopted indicating the source of the document as an abbreviation of the corresponding agency with a consecutive number. This numbering system is used for references within this report.

3. Demand Forecast

3.1 Description of Approach and Methodology

3.1.1 Data background

To provide a basis for a master plan project for the power sector, it is essential that basic data on the historical and present electricity demand as well as demand development in the future are clearly defined. So as a foundation for the demand and load forecast, the available demand data are evaluated.

The analysis of available documents has shown that information on the historical development of electricity consumption is limited for breakdowns by regions and consumer groups. Regionally and sectorally disaggregated data were made available only for the year 1389 (i.e. the period from March 2010 to March 2011) and for the first five reading cycles for the year 1390 (i.e. the period from March 2011 to January 2012) by the time the demand forecast calculations were prepared; for the latter period, though, there are some considerable gaps for various regions and consumer groups, so the 1390 data cannot be considered fully complete. Despite this, the Consultant decided after consultation with Afghan authorities to set up the demand forecast based on 2011 figures, which are approximated by the figures for 1390 (see section on how the Afghan and the Gregorian calendars are handled), which means that the gaps mentioned had to be filled in by estimates and calculations by the Consultant.

This means that the available data for the first five reading cycles in 1390 were complemented by adding the billed quantities in cycle five once more to reflect the estimated consumption level in the sixth reading cycle. This appears reasonable, as both cycles fall in winter and thus are assumed to show a similar consumption pattern and level. In addition, additional gaps in earlier reading cycles in a number of consumer areas and consumer groups were filled by estimates. While this leads to some inaccuracies of basic data, the possible distortions are considered acceptable given the overall level of accuracy of power sector data in Afghanistan.

3.1.2 Regional and sectoral structure

The original set of electricity demand figures for 2011 forming the basis for the demand forecast as well as those for 2010 identified seven consumer sectors, stated as the following consumer categories:

- residential sector (households)
- commercial sector
- registered industrial customers
- unregistered industrial customers
- government
- holy places
- NGOs.

For the demand forecast, it is not expedient to proceed with such a detailed level of disaggregation. It is noted that holy places account for only 0.8% of total billed electricity in 2010, while NGOs account for 0.5% of total electricity demand in the same year. In addition, it can be argued that NGOs and to a great extent holy places have similar functions when compared with the public sector. It is therefore fully justified to combine these three customer groups – government, NGOs and holy places – to the category “public sector”.

Furthermore, there is also no reason for the purpose of the demand forecast to distinguish between “registered industrial customers” and “unregistered industrial customers”. This distinction results from different tariffs for the two customer categories, but not from different demand patterns and attributes. It is also noted that the forces driving electricity demand are the same for commercial consumption as for the industrial sector, namely the development of output. We therefore combine the two industrial costumer groups plus commercial customers into the new customer group “commercial and industry”. For the demand forecast, Fichtner has therefore taken the following three customer groups:

- residential customers
- commercial and industry
- public sector.

Consumption figures for the seven consumer categories for 2010 and 2011 are available for 88 regions and consumer centers, although for many of these the figures are zero. This, too, is excessively disaggregated, so we group the various consumer centers to the level of provinces to obtain 34 provinces, for each of which a demand forecast is prepared.

3.1.3 Explanatory variables and parameters

The general methodology applied is based on a simplified econometric approach that uses the links between explanatory and target parameters, as is the case in econometric analysis. However, it does not base the actual values of the explanatory parameters on (regression) calculations, but on estimates and assessments that are put together from experience in other countries with a similar economic environment and the Consultant’s experience. Such a link of explanatory and target parameters is worked out for the above three consumer groups and broken down by province, while the values for different regions are not expected to differ.

The approach is confined to two main explanatory variables. These are, firstly, income development, be it in the form of available income in the case of the residential sector or growth of economic activity / GDP in the case of the other sectors and, secondly, the electricity price development. The link is then established through the (estimated) income elasticity of demand and the (estimated) price elasticity of electricity demand (in real terms).

Through this approach, the future annual growth of electricity demand is, in general obtained by multiplying the expected future annual growth rate of a sector by its income elasticity of demand for that specific year and adjusting it for a possible downward reaction that results from an increase in tariffs. The impact of the latter depends on price elasticity.

However, the approach as just described can reasonably be applied only in those areas or provinces where there is already an appreciable level of electricity consumption that could provide the basis for the simplified econometric calculation as described. In practice, quite a number of provinces have either zero or very limited electricity consumption from the DABS system. According to DABS statistics, seven provinces have no consumption from the grid at all, while a further sixteen provinces have a consumption of less than 10,000 MWh/a (2010 data) from the DABS grid. Therefore, this econometric approach described in general terms will ultimately be applied only for eleven provinces, which, however, accounted for 98% of total quantities billed by DABS in 2010. The approach will be complemented in the residential sector by adding the additional demand that will result from the expansion of the power system and the subsequent increase of the connection rate of households across the country.

In the following we describe the actual model that is applied for the three customer groups in the provinces with more than 10,000 MWh/a total consumption.

1. Residential customers

Because so far only a limited share of the population is connected to the power system (official figures quote figures of 24% at the end of 2010 and 28% in early 2012 as the share of connected population), the development of the electrification ratio has to be taken into account in the residential sector as a separate factor explaining future residential electricity demand.

The annual growth of expected electricity consumption in the residential sector can thus be expressed by the following equation:

$$g(el)_{tr} = ((1 + g(inc)_t * \varepsilon) * (1 + \Delta T_t * \eta_r))-1 + ((n_t * a) / d_{t-1})/100)$$

with:

$g(el)_{tr}$	=	growth rate of residential electricity consumption in year t
$g(inc)_t$	=	growth rate of real income in year t
ε	=	income elasticity of demand
ΔT_t	=	tariff increase in year t
η_r	=	price elasticity of demand (negatively defined) in the residential sector
n_t	=	number of new residential customers in year t
a	=	average electricity consumption of new residential customers
d_{t-1}	=	residential electricity demand in year t-1

2. Commercial and industrial customers

In the commercial sector, it is not the development of real income that drives electricity demand, but rather the development of economic output or value added. This increased value added will come either from the existing commercial establishments or new ones. It is therefore not necessary to include an element of growth that results from new customers.

Annual growth of expected electricity consumption in the industrial and commercial sector can thus be expressed by the following equation:

$(el)_{tc} = ((1 + g(va)_t * \varepsilon) * (1 + \Delta T_t * \eta_c))-1$

with:

$g(el)_{tc}$	=	growth rate of commercial and industrial electricity consumption in year t
$g(va)_t$	=	growth rate of value added in the commercial and industrial sector in year t
ε	=	income elasticity of demand
ΔT_t	=	tariff increase in year t
η_c	=	price elasticity of demand (negatively defined) in the commercial and industrial sector

The combination of commercial and industrial customers in one group and the use of a common formula for demand growth require that we assume the same values for explanatory variables in the industrial and commercial sectors. Although, for example, in reality there might be minor differences in the growth of output and value added in the commercial and industrial sectors, it is practically impossible to forecast such differences with a reasonable level of substantiation. We therefore consider it justified to combine the two sub-sectors and use the same values for explanatory variables.

3. Public sector

The public sector comprises actual administrative authorities plus public institutions, such as schools, hospitals / health centers, police stations, army camps, as well as, in our definition, NGOs and mosques. For this sector, the level of administrative activities can be seen as the driving force for electricity demand. To be taken as a good proxy for the level of administrative activity is the available budget of governmental bodies and its development, as this not only influences the administration as such, but also all other institutions mentioned. Like for the other sectors, a second variable that impacts future demand is the electricity tariff.

The annual growth of expected electricity consumption in public sector can thus be expressed by the following equation:

$g(el)_{tp} = ((1 + g(bu)_t * \varepsilon) * (1 + \Delta T_t * \eta_p))-1$

with:

$g(el)_{tp}$	=	growth rate of public electricity consumption in year t
$g(bu)_t$	=	growth rate of available public budget in year t
ε	=	income elasticity of demand
ΔT_t	=	tariff increase in year t
η_p	=	price elasticity of demand (negatively defined) in the public sector

As long as a province has a consumption level of less than 10,000 MWh/a in 2010 or shows even zero consumption in DABS billing statistics, it is considered to fall outside those provinces for which the approach and calculation procedure outlined above is applicable.

For these provinces a more straightforward approach is chosen that does not take into account demand by consumer category, but is based solely on the expected development of the connection rate and the average electricity consumption of households. This means that for 23 provinces future demand is obtained by determining the future connection rates of households, which leads – together with the development of population – to the number of households connected in that province, and the average household consumption and its development over time. These 23 provinces accounted for just 2% of DABS billed consumption in 2010, so this approach can be considered justified.

In addition, it must be noted that even in these less developed areas limited electricity consumption arises due to commercial and industrial consumers and some consumption from the public sector. DABS figures for 2010 show that the commercial and industrial sector usually contributes 5% to 10% of total consumption, while the public sector mostly accounts for between 10% and 25% of total demand. As it can be assumed that these shares will slightly increase with economic development, we add 25% to the consumption level obtained for the residential sector in these provinces to reflect the consumption of the other sectors (i.e. it reflects 20% of total consumption).

3.1.4 Further methodological considerations

A number of additional aspects have to be taken into account in the demand forecasting exercise that takes the approach and applies the formulas developed above:

- In line with the requirements of the TOR, an analysis period of 20 years, i.e. from 2012 to 2032 has been chosen, with 2011 as the base year (with some data gaps filled by 2010 data). It is obvious, and generally acknowledged, that every forecasting exercise, no matter what its subject, is fraught with uncertainties. These uncertainties increase with the length of the period of the forecast. Consequently, the forecast carried out by the Consultant should be construed such that it is considered adequate regarding its accuracy for the initial period, which might comprise some five to ten years at the most, with an increasing trend towards uncertainties in subsequent years.

- As uncertainties from unpredictable developments increase over time and there are as well uncertainties stemming either from inadequate or missing current data, we will develop three demand forecast scenarios: Base, Low, and High. This is also a commonly applied approach. The Base Scenario reflects the most likely development. The High and Low Scenarios reflect developments that could realistically materialize, in favorable and non-favorable environments, for key parameters, such as electricity consumption, growth rate of GDP, available budgets or value added, development of applied elasticity values and others. The actual demand is expected to be within the range given by the High and Low Scenarios. This is usually described as the “Cone of Uncertainty” and likewise applies for any demand forecast.

- The results obtained taking the approach and applying the formulas described above relate to net consumption of electricity at the level of the various customer groups. It is therefore necessary to add the transmission and distribution losses to the net figures of demand. Here it will also be necessary to forecast the development of loss levels, as one can expect that DABS will take appropriate steps to reduce the currently high level of losses in the transmission and distribution system. This relates both to technical losses and commercial /

non-technical losses, so that both their respective developments are forecast in terms of a target to be achieved by DABS. In this context it is also assumed that part of the commercial losses will be transferred into actual demand.

- Based on the results of the demand forecast it will then be necessary to calculate the future development of the load for the power system by means of the load factor. Also in this regard we will estimate possible variations of the value of the load factor over time, which would have an impact on future load levels.

The demand and load forecast developed in the way just described will not assume any specific measures for Demand Side Management (DSM) or energy efficiency improvement. Such measures will be analyzed and discussed in the Master Plan in a separate section (3.8).

The approach chosen is, in its general features, quite commonly applied. It is extensively used in an environment in which only limited data are available about the power sector and in particular many structural distortions exist in the development of statistical data. For this reason, the most recent country-wide demand forecast prepared by Norconsult and Norplan in connection with the Power Sector Master Plan 2004 basically applies the same forecast methodology with very minor differences.

3.2 Economic Framework and Development

Afghanistan is one of the poorest and least developed countries in the world. 36% of the Afghan population live below the poverty line (up to 80% in the countryside) and about 75% are illiterate. The total GDP amounted to approximately US$15 billion in 2010. Per capita income stands at around US$600 in 2011/2012.

The last decade has been characterized by annually fluctuating GDP growth rates. Starting at 8.4% in 2003/04, the growth rate dropped to 1.6% in 2004/05 just to soar back to 11.2% in 2005/06. Likewise, the following five years have been marked by distinct ups and downs, reaching an unsustainable peak of 21% in 2009/10 and dropping back to 8.4% in 2010/11. The high levels of volatility are due to, amongst others, the high prominence of the agricultural sector which is subject to weather fluctuations.

Figure 3.2-1 depicts the GDP growth of the past decade.

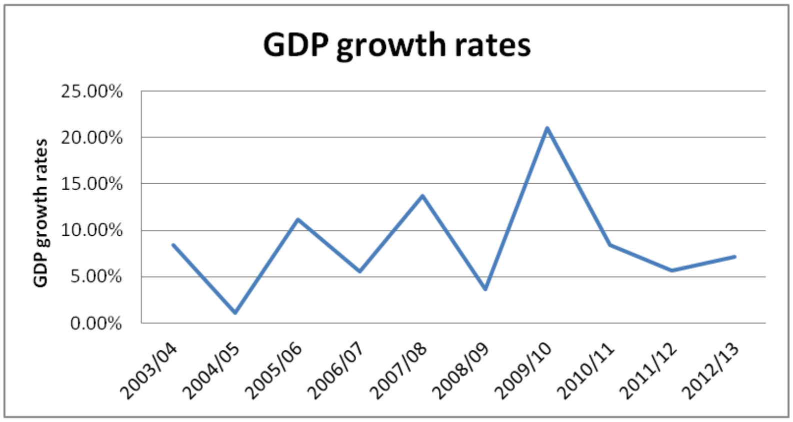


Figure 3.2-1: Development of GDP growth rate

The Afghan economy is mainly driven by the services sector. In 2009/10 it contributed about half of GDP, mostly generated by international transfer benefits. Communication, finance & insurance and transport are the most dynamic subsectors. The agricultural sector accounts for about 30% of GDP. In contrast, industry is of very low importance. After decades of war and political instabilities the country lacks a skilled and qualified work force, most of the infrastructure is destroyed, and new production facilities are rarely built for fear of destruction. In addition, the country is of limited competitiveness due to its relatively high labor costs in the labor-intensive sectors. Instead, Afghanistan bears the risk of high reliance on imports and had a trade deficit of about 40% of GDP in 2011.

Another aspect that has been fuelling growth of the Afghan economy in the past half-decade is private consumption, which attained a growth rate of over 9% on average during this period. Furthermore, investment has been showing moderate growth (around 2.3% on average) over recent years, mostly from the external-budget capital spending and private investment in the security sector.

Since FY 2005/06, external trade has been gradually declining. In 2010/11 imports declined from 61% to 53% of GDP, mainly because of a reduced demand for goods in donor-funded projects as well as blockages at the Pakistani border. Exports fell slightly from 17% to 15%, reflecting a small reduction in agricultural exports.

Afghanistan's illicit sector is estimated to be in the range of one third to one half of the country's GDP. Opium cultivation provided income for approximately 5% of the Afghan population in 2011, exports are estimated to have reached up to US$2.8 billion in 2010 (about 19% of GDP).

Afghanistan has vast deposits of natural resources: iron ore, copper, gold, lithium, rare earths and gemstones as well as oil and gas in very large quantities. However, prospecting for and development of these is still in its infancy due to the country's complex geology and the security situation. The resources are estimated at US$3 trillion. Investments in mining and infrastructure development are needed to exploit the sector's potential, which is expected to be able to contribute up to 5% of annual growth. In late 2010, the government took action to develop the first oilfields, which is an important step to reduce dependence on foreign fuel and to generate tax revenues. Gold production is planned to begin in 2013.

In 2008, the first foreign firms, mostly from China, India and Canada, were awarded contracts to exploit the Afghan oil and natural gas reserves as well as to develop copper and gold mines. As part of the Aynak Copper Mine contract, China undertook to construct a railway to connect Kabul to Pakistan and Uzbekistan, which is an important infrastructure project for linking Afghanistan to transcontinental railways and fostering its exports.

Consumer prices rose significantly by 13.7%, in 2010, reversing a previous deflationary trend. Rising from 2% in June 2010, the inflation rate peaked at 18% in the period from January to April 2011, mainly driven by the increase in fuel and transportation costs of imported goods and rising food prices. It has since moderated to 11% in August 2011; core inflation rose from 5% to 13%.

Domestic revenues are currently at 11% of GDP but are expected to increase up to 16.4% by 2021/22 thanks to improvements in tax collection and administration as well as customs duties. The sales tax – 2% BRT on imports and 10% BRT on services – was the largest component. The introduction of a value added tax is planned for 2014. Nevertheless, total expenditures are projected to rise to around 43% of GDP by 2021/22, leaving an estimated financing gap of about 25%.

Especially following the Kabul Bank crisis in 2010, the fragility of the financial sector and the limited capacity of the Central Bank to effectively supervise the banking sector and enforce regulations and banking law were highlighted. The bank has since been put under receivership. Its license has been revoked and shareholders' rights and interests have been extinguished. A bridge bank, the New Kabul Bank, has been established and is planned to be put out for sale to a qualified investor who contributes sound banking sector experience to reinvigorate Afghanistan's stagnant banking sector.

Afghanistan is extraordinarily dependent on foreign aid. Receiving over US$56 billion of development assistance between 2002 and 2010, foreign aid has been equivalent to an average of 78% of Afghan GDP since 2003. With the planned troop withdrawal in 2014 and an expected gradual decline of foreign aid, Afghan growth rates are likely to decrease, leaving the country facing a financing gap of up to 25% of GDP by FY 2021/22, mainly due to the security sector and operating & maintenance costs. If aid decreases to 10% of GDP by 2025, the World Bank forecasts GDP to grow on average by 5.9% per annum during 2011–2018, and 3.9% thereafter. In case of a rapid decline – aid decreases to 10% of GDP by 2018 – the growth rates would fall to 5.2% over the same period of time and to 3.7% thereafter.

According to the IMF, real GDP is going to grow by 6.2% on average until 2014 and then decline over the long term to between 5.4% and 6.6%, leveling off at 4% with occasional peaks thanks to the mining production cycle.

The US Treasury expects GDP growth rates to lie between 2.4% and 4.9% after 2014, depending on the foreign aid cut.

The demographic transition represents an additional problem the government needs to manage, as 60% of the Afghan population is less than 25 years old. An unemployment rate of currently 40%, if left to continue, could fuel poverty, social unrest and vulnerability.

Needless to say, the Afghan economy is in a weak state: over the long term the outlook is mainly characterized by a high level of insecurity. Social and economic improvements in the past have only been made possible by international support. Whether or not the government is capable of successfully managing the transition, ensuring political stability and fiscal sustainability, fostering mining projects and generating new jobs remains to be seen.

3.3 Assumptions and Key Parameters for Load Forecasting

In this section, we discuss the assumptions we apply for the load forecast and the values that we attribute to the various key parameters.

Gross domestic product
As set out in section 3.2, the development of GDP growth rate has been quite volatile over the past about ten years. This makes it difficult to accurately forecast future GDP development. Nevertheless, annual GDP growth has almost always exceeded 5% during this period. Given the strong international support that will also continue in the near future, reasonable growth levels can also be expected over the next couple of years. In addition, the expected withdrawal of foreign troops in 2014 and possible changes in economic cooperation with donor countries thereafter have to be taken into consideration. This could lead to impacts on economic growth.

It has also to be noted that, as a result of substantial support from abroad, international financing institutions have continuously monitored economic development in Afghanistan and advised the country on its economic recovery. As a consequence, these institutions have a wealth of information on the Afghan economy and are thus best suited to assess future economic development in the country. We therefore take the forecast of the International Monetary Fund (IMF) as the basis for future growth rates. This forecast reckons with a 7.1% growth in 2012 and around 6% per annum until 2018. Thereafter it is expected to decline gradually to around 4% up to 2025 and to remain at a level of 4% per annum after 2025. In addition, we assume that the industrial and commercial sector will increase one percentage point above the average growth rate of GDP, as the industrial sector, given its currently low level, is expected to increase its share in the economy as a whole.

The annual growth of GDP per capita determined from the above-mentioned bases is given in the following Table 3.3-1.

Year	GDP growth per capita	Year	GDP growth per capita	Year	GDP growth per capita
2012	5.0%	2019	3.5%	2026	2.1%
2013	3.70	2020	3.4%	2027	2.1%
2014	3.9%	2021	3.3%	2028	2.2%
2015	4.1%	2022	2.9%	2029	2.2%
2016	4.3%	2023	2.4%	2030	2.2%
2017	4.5%	2024	2.0%	2031	2.3%
2018	4.0%	2025	2.0%	2032	2.3%

Table 3.3-1: Summary of basic assumptions for the demand and load forecast

Income elasticity of demand

Usually the income elasticity of demand is derived from past figures and development. In Afghanistan, though, such long-term time series data are not available. So for this parameter, the actual values used in the forecast have to be estimated from other countries and plausibility considerations. The income elasticity figures have to be applied for each of the three main consumer categories individually, although in general elasticities are not expected to show large variations between sectors. We base our estimates on the following considerations:

- For the residential sector it is often argued that in low income countries with a comparatively low level of electricity demand, income elasticity can considerably exceed parity, i.e. a value of 1, and reach values as high as 1.3 to 1.5 and sometimes even more. It must be noted, though, that such elasticity figures relate to the entire residential sector and thus include additional demand from new connections as well.

  The approach applied in this study makes a distinction between the future demand of existing customers and added demand from new customers as a separate item, as described above. Thus income elasticity applies only to customers that are currently already connected to the grid. Here increasing income often means that households can afford new electricity consuming appliances, but high income groups might reach some level of demand saturation. This means that income elasticity of demand might lie slightly above parity, but ultimately not much, so we reckon with a value of 1.1 for the residential sector.

- In commerce and industry, the income elasticity of demand depends entirely on the type of future industrial (and commercial) establishments. If heavy, energy-intensive industry is implemented, income elasticity can considerably exceed unity. If growth in services, commercial establishments, and light industry is the driving force in future, income elasticity will be below unity. While we tend to assume that prospects for heavy industry are not that promising, it is practically impossible to reasonably predict the structure of future industry and of the commercial sector and their respective shares. We therefore consider it prudent to take a value of 1 as a kind of average assumption for the income elasticity of demand in the commercial and industrial sector.

- For the public sector, the general assumption is that in times of limited budgets decision makers will give priority to spending for items other than electricity or new electrical appliances. We therefore assume that income elasticity of demand in this sector is slightly below parity and amounts to 0.9.

Development of the electricity tariff

The current average tariff level has been calculated on a regional / provincial basis on the basis of billed consumption figures obtained from DABS; the consumption figures are stated both as physical units (kWh) and costs (Afs), which allows a per unit (i.e. average tariff) calculation. This shows minor differences in various load centers where the general tariff is applied. Billed quantities and amounts are given for various consumer groups and can thus be calculated for the three aggregated consumer groups used in the demand forecast. While these tariffs apply for the vast majority of consumption, there are some provinces with very limited consumption where considerably higher tariff levels apply. As this second group accounts for less than one percent of total net demand, it can be neglected.

It is to be noted that the current tariff level of between around 4 and 7 US-cent/kWh for residential customers in most large load centers (Herat, for example, shows an average residential tariff of 5.35 US-cent/kWh, while this value is 6.88 US-cent for Kabul) is far from being enough to cover costs. While we have no information on a cost-covering tariff level or the level of Long Run Marginal Costs (LRMC) in Afghanistan, we tend to assume that, given the fact that the entire system, in particular the transmission and distribution system, must be practically rebuilt from scratch, a value of 15 US-cent/kWh might be a very rough estimate to reflect a possible cost-covering tariff. This is based on the assumption that power generation will cost some 6 to 8 US-cent/kWh on average, while power transmission and distribution, taking into account losses, will cost some 7 to 10 US-cent/kWh.

We further need to assume that it will take the Afghan Government some time to increase tariffs. Representatives from DABS and the Ministry of Energy and Water have already indicated in meetings that tariff increases have to be treated as a politically sensitive issue that requires considerable time to achieve. We therefore reckon that this level will be attained ten years from now. This means that average residential electricity tariff increases will be between 4.5% and 15% per annum, depending on the current level of tariffs in a load center in the period up to 2021. Thereafter, no further tariff increases in real terms are assumed.

In practically all large load centers, the average tariff for industrial, commercial and public consumers is, unlike the situation in the residential sector described above, of an order of magnitude of 15 US-cent/kWh. In those cases where the tariffs are below this level, we assume an increase, while if the tariffs are currently slightly higher we do not assume any modification.

Price elasticity of demand

There are no specific recent analyses of price elasticity available for the Afghan power sector. It is therefore necessary to deduce the values for Afghanistan from other countries. Experience from other countries with a similar economic background and framework indicates that the price elasticity for electricity is usually very low. One can generally assume that the price elasticity of demand is somewhere in the order of magnitude of -0.1 to -0.3.

We will therefore apply this range for our analysis and demand forecast. However, we will use slightly differing figures for the various sectors.

- The commercial and industrial consumers usually have a larger interest, driven by economic and profitability considerations, to react to increasing electricity tariffs; they mostly also have some means available to implement energy efficiency measures that can cut consumption. We therefore assume that the commercial and industrial sector is at the upper limit of the range mentioned and we use a value of -0.3 for this group of consumers.

- In the public sector, one can expect a less pronounced reaction to tariff increases, as generally it is not "own" money that is spent for electricity; moreover, in times of very tight public budgets, which will prevail in Afghanistan also in coming decades, there are usually no funds available that could be used for implementing energy conservation measures. We thus apply a value of -0.1 for the price elasticity of demand in the public sector.

- Finally, in the residential sector, we would expect an attitude towards price increase that lies between the two consumer categories as discussed above. We therefore reckon with a price elasticity of demand in the residential sector of -0.2.

However, as we have mentioned that there are major deviations from the estimated cost covering tariff only in the residential sector, only the price elasticity of demand for residential customers will ultimately play a role in the forecast.

Connection rate

As mentioned, the overall connection rate in Afghanistan is very low. In 2010, only 24% of all households in the country were connected to the electricity grid of DABS; this figure increased to 28% in 2011. This is, however, still far from satisfactory. The situation is better in a number of large load centers, such as Kabul (44% in 2011), Herat (82% in 2011) and Balkh (63%), but even in these places, additional connections are required. DABS is therefore planning to substantially increase the connection rates in the shortest possible time.

We thus make the following assumptions with regard to connection rates in the various regions in the country:

- Major emphasis will be put on an increase of the connection rates in large cities. Kabul and Herat are therefore assumed to reach 90% connection rates within five years, while in Balkh and Kandahar 80% will be connected in the same period.
- Those provinces that currently show a connection rate level of between 10% and 20% shall reach 60% within five years, while those with a current connection rate of above 20% are expected to achieve a 70% target in 2017.
- For those provinces with currently less than 10% connection rate, we consider 50% as the target value. While the regions that are already connected to a DABS system today, even if at a very modest level, are expected to achieve this level in 2020, the provinces that are currently not connected are expected to reach this level in 2023.

- In the special case of Nimroz, which according to DABS statistics already has a connection rate of 98%, it is assumed that this will increase to 99% shortly.
- After these target dates in 2017, 2020 and 2023, the grid connection rates are expected to further increase gradually and to reach between 65% and 99% in 2032.

Unserved energy

While DABS has pointed out on several occasions that not all customers can be served as desired, we need to acknowledge that estimating the level of unserved energy in general, but in particular in an environment such as in Afghanistan, is a most difficult undertaking and a somewhat hypothetical exercise. We must also note that unserved energy, in a country in which less than 30% of all households are connected to the utility's electricity system, means in the main unserved energy for those that are not connected. This problem will be solved by DABS with a strategy of rapidly expanding the system and connecting new customers. This issue is reflected in the demand forecast by increasing connection rates for all provinces and is therefore not dealt with under "unserved energy".

Only the second aspect of unserved energy is thus addressed specifically in the forecast, namely the fact that those customers that are already connected to the electricity system cannot always and at all times be supplied with the quantity of electricity they would like to consume. Since there are no surveys or other research data available on unserved energy, DABS tries to estimate the level of unserved energy hands on and comes to the conclusion that, at peak load hours, about 20% of the required energy cannot be supplied. This is primarily a figure given for Kabul and Northwest Afghanistan, but the situation in other areas, according to DABS' assessment, will not be much different. We consider this figure as a reasonable order of magnitude and factor it into the load forecast. While it relates to the peak load time, we estimate that overall energy unserved throughout the year amounts to around 10%. It can be assumed that the situation with regard to unserved energy varies from province to province, but due to a lack of data we have to assume the same level throughout the country. With an increasingly connected transmission system, this is expected to level out in any case.

Household consumption level

Current average household consumption levels differ substantially between the various provinces and grid systems. The average residential consumption is comparatively high in the main load centers, such as Kabul, with slightly more than 3000 kWh average residential consumption in 2011, and Herat, with close to 2600 kWh.

In most provinces connected to a DABS system, though, average household consumption is quite low, ranging from as low as 178 kWh/a in 2010 in Ghor province to 551 kWh/a in Laghman province in the lowest segment. This group covers twelve provinces that are expected to reach an average consumption level of 1400 kWh/a for the residential sector in 2020. Another group of six provinces with currently "zero" consumption from DABS systems is expected to achieve the same level of 1400 kWh/a per household somewhat later in 2023.

Another group of nine provinces with a currently higher average household consumption, in the range of 900 kWh/a to 1200 kWh/a, is likely to maintain this higher level and reach some 1800 kWh/a in 2020.

For the remaining seven provinces (including Kabul and Herat, as mentioned above) the approach differs slightly from the overall approach, with the average consumption of newly connected households used as a parameter and not the future average of all residential customers. We assume for Kabul and Herat that a new residential customer would consume on average around 50% of the current average residential consumption level, while this would be 70% and 80% in the other provinces, depending on their current average consumption levels.

Technical and commercial losses

Technical and commercial losses are extremely high in Afghanistan. When figures of total available gross electricity (generation sent out and imports) are compared with the total billed quantity, we obtain a share of around 45% to 46% of net demand (billed quantity) as losses. (At this point it is emphasized that, for the sake of ease of calculation of future demand, losses, i.e. the 45% value, are defined as a proportion of net demand and not as a proportion of electricity generated / imported, as is often done in other statistics.) There is minimal uncertainty in this figure, as the available energy is given for 2011, while the billed quantities are given for 1390, so that the latter need to be adjusted. This distortion, however, is estimated to be in the range of 1% to 2% only. We therefore reckon with total losses of 45% of net demand initially. As technical losses can hardly exceed 15%, we assume that commercial losses account for 30% and the technical losses for 15% of net demand.

It is clear that such a situation cannot prevail for long and that DABS needs to combat the high level of losses. In particular, the commercial losses need to be reduced. We therefore consider a target for commercial losses of 13% in 2021 and 10% in 2026 as realistic and achievable. Thereafter we expect a further decrease by 0.3 percentage points per year, so that in 2032 commercial losses would stand at about 8%. This is still considerable, but given the current level it would already be a substantial achievement.

Concerning technical losses, we assume a slower rate of decrease. It is expected that technical losses will decrease by 0.3 percentage points per annum and reach 10% in 2028. Thereafter it will further decrease by 0.2 percentage points per annum.

Load factor

The estimate of the load factor is one of the most critical issues in the demand and load forecast for Afghanistan. DABS does not collect specific information on peak load in its various systems. On the basis of the given data, the load factor can thus be calculated only for Kabul and Herat, where sufficient information is available. This shows widely differing results. In Kabul, the load factors for 2010 and 2011 amount to 56% and 53% respectively. We reckon initially with a load factor of 53% in Kabul, in order to be on the safe side. On top of this the effect of unserved energy has to be applied. As this leads to a comparatively low level, it is assumed that the load factor increases over time by one percentage point per annum until it reaches 60% in 2023 and remains at this level thereafter.

In Herat the load factor calculated for 2010 is 78%, which is quite high. Even if we take the unserved peak load into account, the load factor amounts to 71.5%. We therefore assume that in this region the load factor is going to decline gradually over time to reach 60% in 2032.

For all other provinces we assume, taking into account unserved energy, an initial load factor of 55%. This will increase gradually over time to 60% in 2028 and remain at this level thereafter.

Summary of assumptions for the base case

Table 3.3-2 summarizes the assumption for the demand forecast in the base case scenario, as discussed above.

Parameter	Unit	2012	2015	2020	2025	2030
GDP growth rate	%	7.1%	6.2%	5.5%	4.0%	4.0%
Income elasticity, households	-	1.1	1.1	1.1	1.1	1.1
Income elasticity, industry	-	1.0	1.0	1.0	1.0	1.0
Income elasticity, public	-	0.9	0.9	0.9	0.9	0.9
Average power price, residential	US-cent/kWh	from 4.9 to 10.6	from 7.4 to 12.0	15.0	15.0	15.0
Price elasticity, residential	-	0.2	0.2	0.2	0.2	0.2
Price elasticity, industrial	-	0.3	0.3	0.3	0.3	0.3
Price elasticity, public	-	0.1	0.1	0.1	0.1	0.1
Technical losses	%	14.7%	13.8%	12.3%	10.8%	9.6%
Commercial losses	%	28.3%	23.2%	14.7%	10.6%	8.8%
Load factor (exc. Kabul/Herat)	-	0.553	0.562	0.577	0.592	0.60

Table 3.3-2: Summary of basic assumptions for the demand and load forecast

Basic assumptions in the scenario cases

As mentioned, in addition to the base case scenario, low and high scenarios have been developed. The variables, for which we assume modifications in the high and low scenarios, are related to overall economic development, consumption level and connection rates. In addition, in the high scenario the development of the future tariff level plays a role.

We thus assume in the high scenario a favorable economic development and consequent higher consumption by customers, which is expressed by a 10% higher growth rate of GDP and an income elasticity of demand that is 0.1 points higher than in the base case. In addition, average consumption for households in those provinces with a currently low average consumption is assumed to be 20% above the base case scenario level. Furthermore, we assume in the high scenario that DABS will not increase the average tariff to the level of 15 US-cent/kWh, but only to 12 US-cent/kWh, i.e. 20% less. But due to the comparatively low price elasticity of demand, this effect is limited.

In the low scenario, we assume that the negative deviations from the base case are somewhat more pronounced than in the high scenario. We thus reckon in this case, in addition to a change in the income elasticity of demand by -0.1 points, with a 20% lower growth rate of GDP and the related economic figures of available income, budget, etc. Furthermore, we assume a 20% lower average household consumption in the said provinces and 10% lower connection rates in the majority of provinces, while in large customer centers, the connection rate is 5% lower. The average tariff level is assumed to not change in the low scenario.

3.4 Forecast of Total Demand for Afghanistan

Figures 3.4-1 to 3.4-3 show the results of the demand and load forecast for the whole of Afghanistan. Each of the three figures depicts the three scenario cases, first for net demand, then for gross consumption (sent-out electricity) and finally for the peak load. Details in table form are given in **Annex 3.4**.

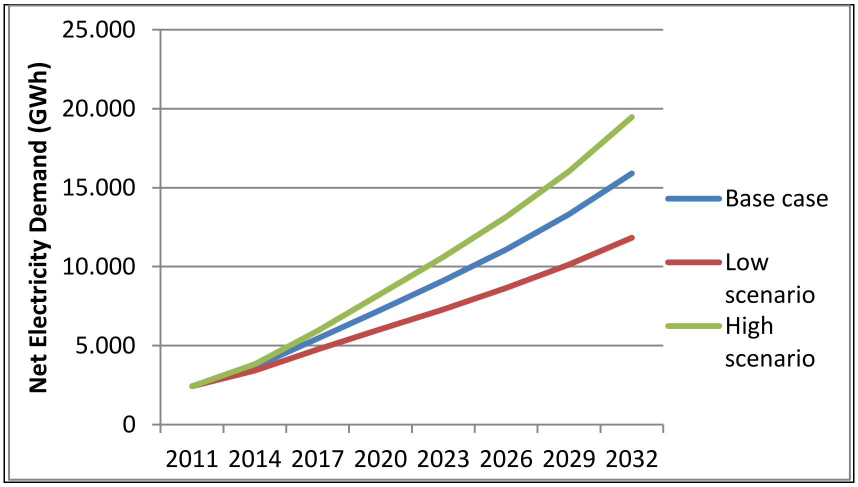


Figure 3.4-1: Development of net electricity demand in Afghanistan

Net demand shows the steepest increase of the three variables. From its present level in 2011 net demand is expected to increase by a factor of more than 7 to 15,909 GWh in 2032 in the base case. This means an average annual growth rate of 9.8% during this period. The growth rate in the beginning is higher, as a substantial increase of the number of connected households is expected initially as well as an increase of the average household consumption, while the residential sector is the driving force in energy demand in Afghanistan in any case. Between 2012 and 2017, average annual growth is 14.1%, which decreases to 9.2% per annum in the second five-year period from 2017 to 2022 and levels out at an average annual growth rate of 6.2% in the last five year period.

In the case of the low scenario, total net demand in 2032 is expected to reach 11,840 GWh, which means an increase by a factor of 5.3. Net demand is thus 26% lower in the last year of the forecasting horizon than in the base case scenario.

In the high scenario, total net demand would be 19,474 GWh in 2032 or 22% higher than in the base case. This would be an increase by a factor of 8.8 from the current level.

Gross demand growth is somewhat lower than the increase in net demand, as shown in Figure 3.4-2. Between 2011 and 2032, gross demand (energy sent out) increases by a factor of 5.7, which means an average annual growth rate of 8.7%. The major reason for the slower growth is that the demand forecast assumes substantial reduction in both technical and commercial losses. Energy sent out is forecast to reach a level of 18,409 GWh in 2032. In the first five years from 2012 to 2017 gross demand increases by 12.2% per annum, a value that decreases constantly over time and stands at 5.7% average annual growth from 2027 to 2032.

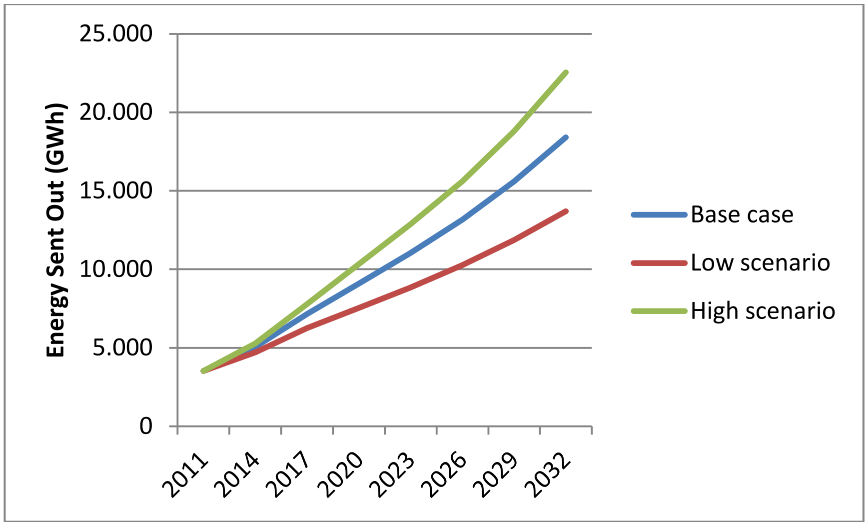


Figure 3.4-2: Development of energy sent out in Afghanistan

In the low scenario, total sent out electricity in 2032 would amount to 13,701 GWh. This is an increase by a factor of 4.3 over the current level of consumption and corresponds to an annual average growth rate of 7.2%.

In the high scenario, electricity sent out would reach 22,534 GWh, which reflects an average annual growth rate of 9.7% from the present up to 2032.

Peak load in Afghanistan increases by a factor of 5.7 from its current level to 3502 MW in 2032 in the base case, as can be seen in Figure 3.4-3. The average annual growth rate in this period stands at 8.6%. This is marginally lower than the increase in gross demand and results from a marginally higher average load factor in the country in 2032. In the initial five year period from 2012 to 2017, the annual average growth rate is 11.3%, which decreases to 6.8% per annum in the following five years and to 5.8% per annum in the last five years of the forecasting horizon.

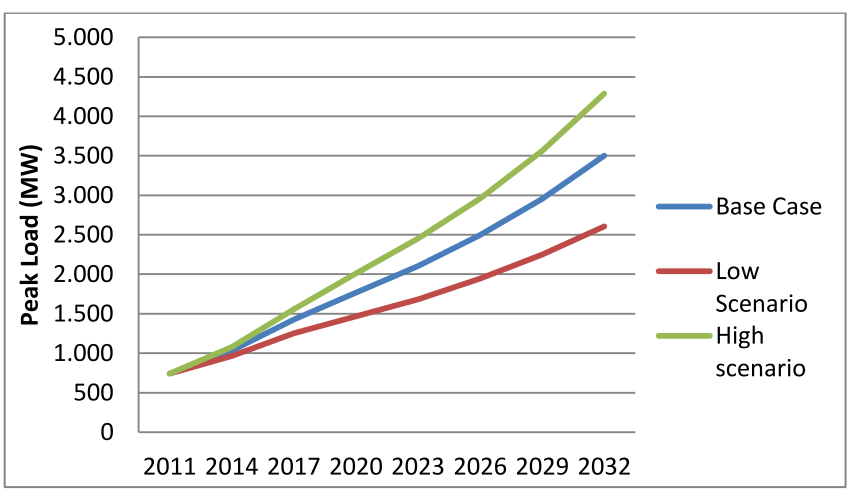


Figure 3.4-3: Development of peak load in Afghanistan

Peak load in the low scenario amounts to 2607 MW in 2032, 26% lower than in the base case scenario. It reflects an increase by a factor of 4.2 from the current level and an average annual growth rate of 7.1%.

In the high scenario, peak load would reach 4287 MW in 2032, corresponding to an average annual growth rate of 9.7% between the present and 2032, and is 22% higher than in the base case scenario.

The basis and general methodology used for demand forecast as well as the results achieved have been discussed intensively during the meetings held for the different phase of the project. The conclusion at the end of the discussion was that the result of the demand forecast is based on proven methodology and gives the best estimation possible for the uncertainties in general in that matter and especially for Afghanistan situation.

3.5 Demand Forecast by Region

As the approach of the load forecast is disaggregated by provinces, detailed results for each province are available. However, in order not to overload the presentation of results with 34 individual tables for each province, many of them with only quite limited demand even in 2032, in **Annex 3.5** we show the results individually for those five provinces that reach a peak load of more than 100 MW in 2032 and, taken together, account for close to 60% of total peak demand in the country. An example is also given for a province with an initial demand of less than 10,000 MWh/a, for which the approach is based on the connection rate of the residential sector and average household consumption.

In addition, for a number of regional areas that are compiled in accordance with existing grid patterns, regional demand forecast results are presented in the following. To this end, we have formed the following consumer areas:

- Kabul area, including the city and province of Kabul plus the provinces Laghman, Logar, Nangahar and Paktiya
- NEPS TKM, including Faryab, Jowjzan and Sar-e-Pul provinces
- NEPS UZB & NEPS TAJ, including Baghlan, Balkh, Kunduz, Parwan, Samangan and Takhar provinces
- SEPS, encompassing Helmand and Kandahar provinces.

Kabul Area

Net electricity demand in the Kabul area (as defined above) is expected to increase to between 4809 GWh (low scenario) and 7901 GWh (high scenario) in 2032, while the base case scenario shows a level of 6394 GWh, as can be seen in Figure 3.5-1. It means for the base case scenario an increase by a factor of 5.8 between the 2011 peak and 2032, or an average annual growth rate of 8.8%. This factor is lower than for Afghanistan as a whole. The reasons are that Kabul already has a comparatively high connection rate as well as a high average household consumption, so that in both these areas future increases are somewhat lower.

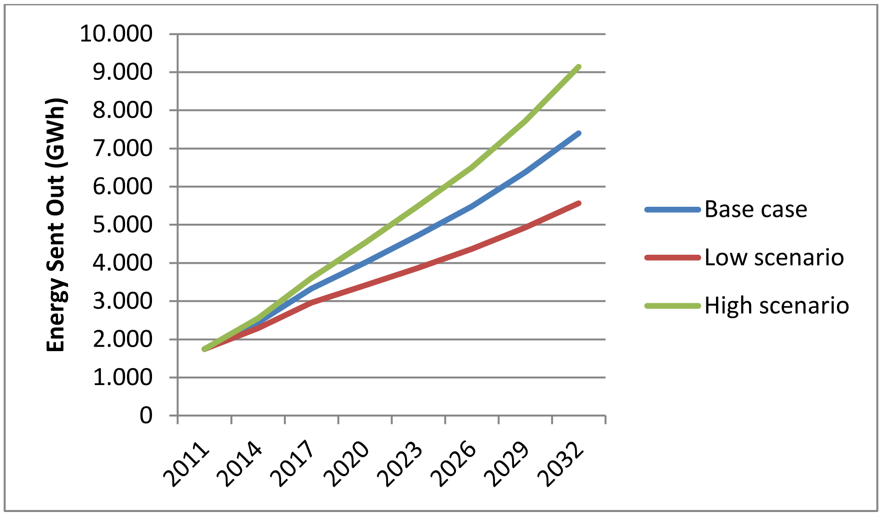


Figure 3.5-1: Development of net electricity demand in the Kabul area

Figure 3.5-2 shows the development of gross energy sent out from power plants for the Kabul area in the period up to 2032. In the base case scenario, Kabul area is forecast to be supplied with 7401 GWh in 2032, while in the same year in the low scenario this would be 5566 GWh and in the high scenario 9145 GWh. This means an average annual growth rate of 7.6% or an increase by a factor of 4.7 in the base case scenario, which is lower than for net demand, as we assume decreasing levels of losses, as explained earlier.

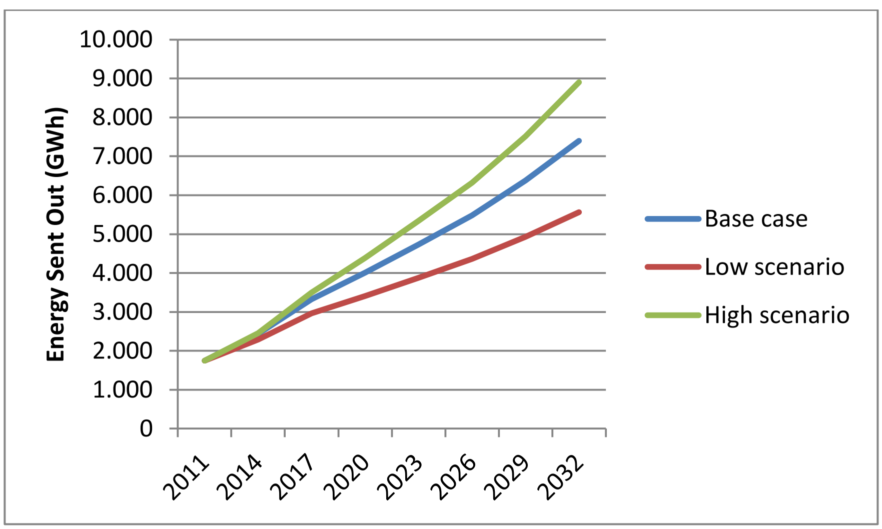


Figure 3.5-2: Development of energy sent out in the Kabul Area

In Figure 3.5-3, the development of the peak load in Kabul area is depicted. The forecast shows a peak load of 1408 MW in the Kabul area in 2032 in the base case scenario. In the case of a more favorable development, the high scenario would lead to a peak demand of 1740 MW, while the low scenario, reflecting a less favorable development, would lead to a peak load of 1059 MW. In line with the assumption that the load factor increases over time in Kabul from its currently low level, the growth of peak load is lower than the development of energy sent out. The average annual growth rate of the peak load in Kabul area is 7.0%, so that in total the peak load increases by a factor of 4.1 during the forecasting horizon.

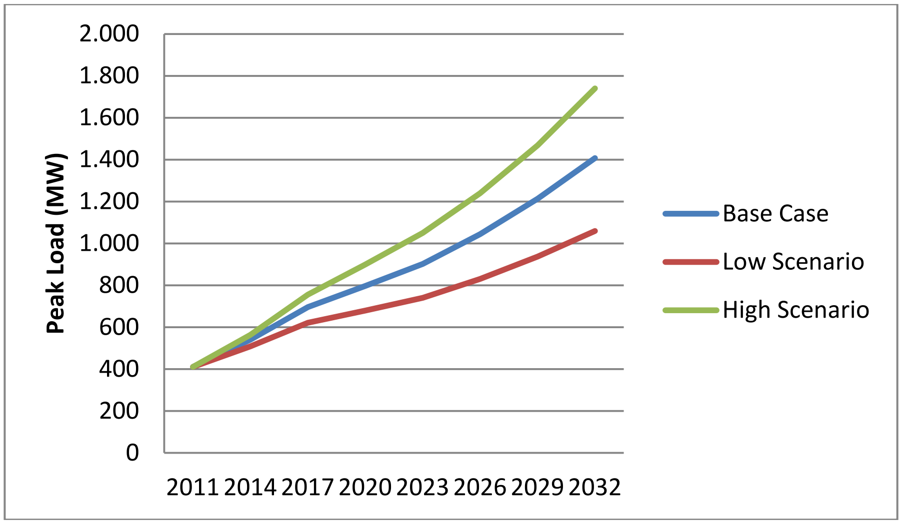


Figure 3.5-3: Development of peak load in the Kabul Area

For Kabul province, we address in the following in addition the issue of seasonal variation of demand, i.e. the question as to what extent consumption during winter is higher than in the summer period. The results can be summarized by the conclusion that these seasonal variations are very pronounced. When we look at the years 2010 and 2011, we see that gross demand from October to March (winter period) is higher by about 42% in 2010 and 48% in 2011 than during the summer period (April to September). For 2011, we need to take into account, however, that additional capacity was made available to Kabul at the end of the year through the NEPS line, which explains the exceptionally high consumption in December 2011. Without this effect the ratio between winter and summer in 2011 would also be more in the range of 1.4 (i.e. 40% higher in winter than in summer). Moreover, these values are related to gross consumption, so that, taking into account higher losses at times of higher demand, the difference of net demand is slightly lower. Figure 3.5-4 shows the monthly gross consumption in Kabul province in 2010 and 2011.

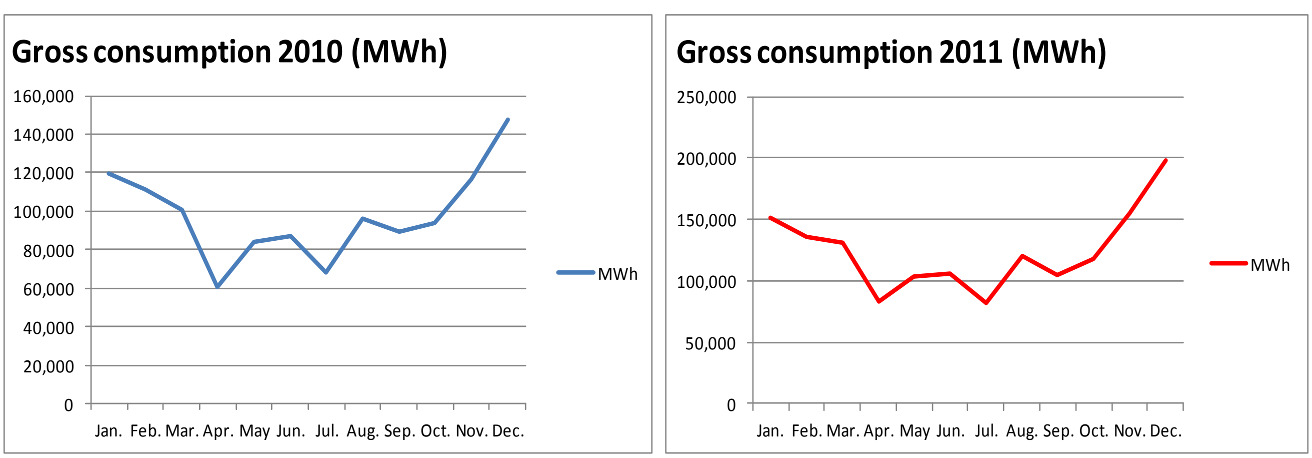


Figure 3.5-4: Monthly gross consumption in 2010 and 2011, Kabul province

The situation is similar with regard to the variation of the peak load between winter and summer. In 2010, the winter peak was 32% higher than the lowest summer month peak, while in 2011 it was 58% higher. However, the higher value in 2011 is again explained by the fact that additional capacity was made available at the end of 2011. If we leave November and December values aside, the difference is 35% for 2011. These are again gross values, so that net values are somewhat lower due to higher losses during peak times. Figure 3.5-5 shows the monthly peak demand values for 2010 and 2011.

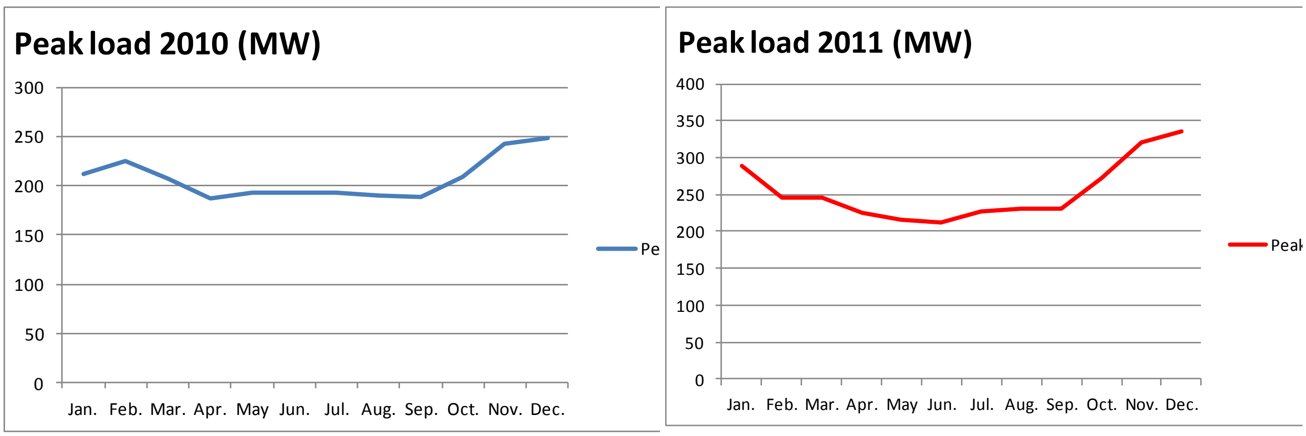


Figure 3.5-5: Monthly peak loads in 2010 and 2011, Kabul province

NEPS TKM

Net electricity demand in the NEPS TKM area (covering Faryab, Jowjzan and Sar-e-Pul provinces) is expected to increase to between 680 GWh (low scenario) and 1014 GWh (high scenario) in 2032, with the base case scenario showing a level of 888 GWh, as depicted in Figure 3.5-6. The base case scenario thus increases by a factor 8.8 between the current level in 2011 and 2032. This means an average annual growth rate of 10.9%. This factor is considerably higher than for the whole of Afghanistan, as the three provinces have to catch up from comparatively low connection rates and low average household consumption levels.

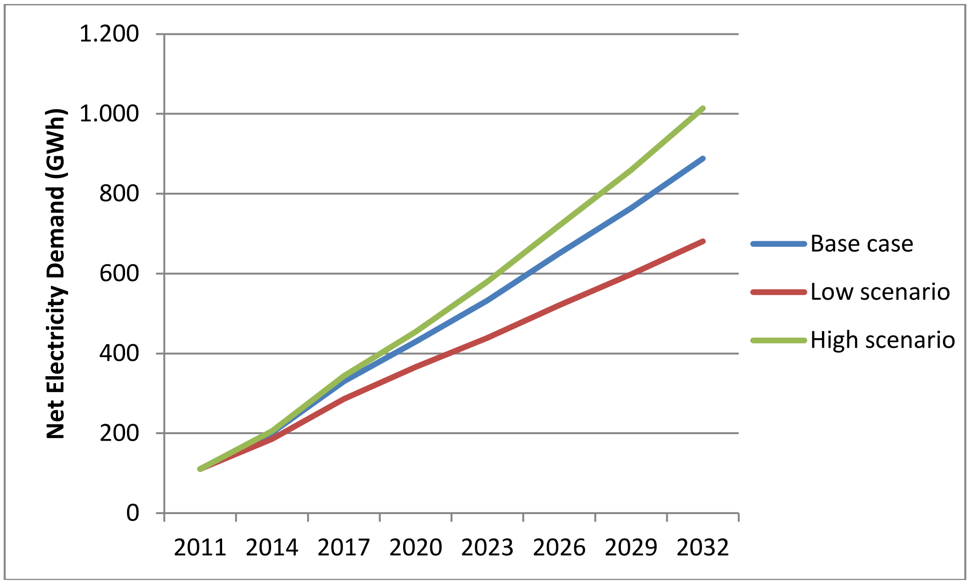


Figure 3.5-6: Development of net electricity demand in the NEPS TKM area

Figure 3.5-7 shows the development of gross energy sent out from power plants for the NEPS TKM area in the period up to 2032. In the base case scenario, this area is forecast to be supplied with 1027 GWh in 2032, while in the same year in the low scenario this would be 788 GWh and in the high scenario 1174 GWh. This means an average annual growth rate of 9.7% or an increase by a factor of 7.0, which is lower than for net demand, as we assume decreasing levels of losses, as explained earlier.

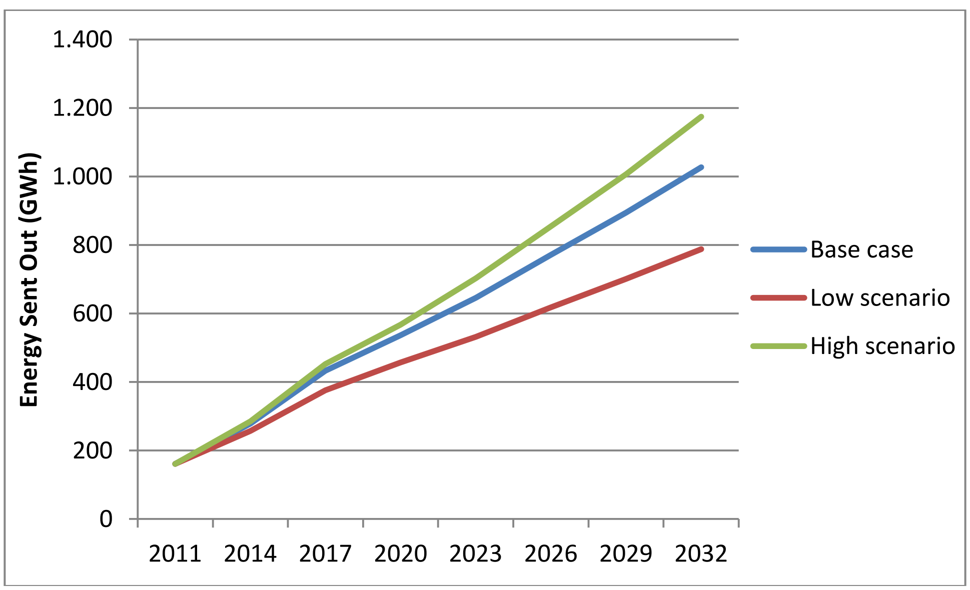


Figure 3.5-7: Development of energy sent out in NEPS TKM area

Figure 3.5-8 shows the development of the peak load in the NEPS TKM area. The forecast indicates a peak load of 195 MW in this area in 2032 in the base case scenario. In the case of a more favorable development, the high scenario would lead to a peak demand of 223 MW, while the low scenario, reflecting a less favorable development, would lead to a peak load of 150 MW. The average annual growth rate of the peak load in the NEPS TKM area is 9.7%, so that in total the peak load increases by a factor of 7.0 over the forecasting horizon.

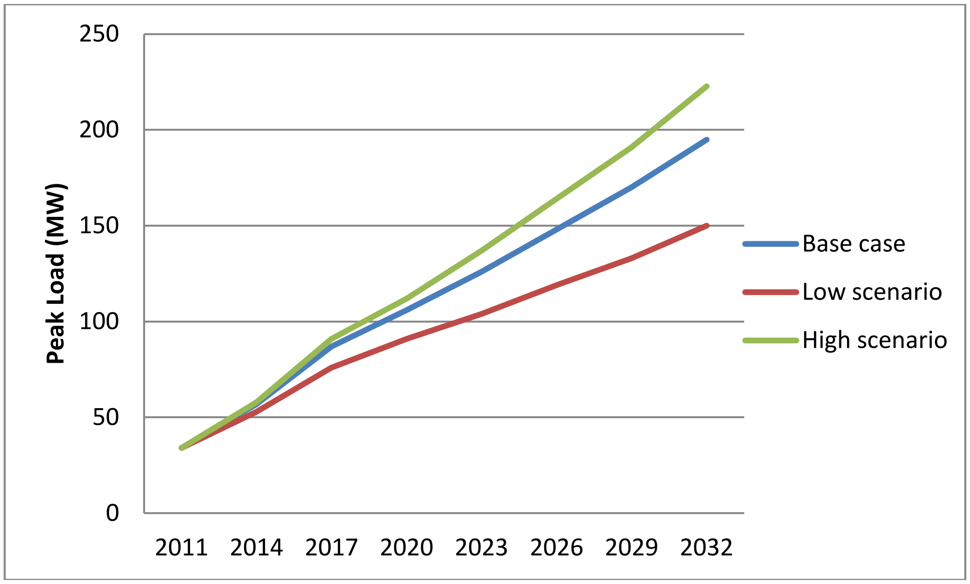


Figure 3.5-8: Development of peak load in the NEPS TKM area

NEPS UZB & NEPS TAJ

As shown in Figure 3.5-9, net electricity demand in the NEPS UZB & NEPS TAJ area (with the six provinces given above) is expected to increase to between 1813 GWh (low scenario) and 3014 GWh (high scenario) in 2032, with the base case scenario showing a level of 2467 GWh. The base case scenario for this area thus increases by a factor of 8.6 between the current level in 2011 and 2032. This means an average annual growth rate of 10.8%. This factor is considerably higher than for the whole of Afghanistan. This results from the fact that the six provinces currently show comparatively low connection rates and low average household consumption levels.

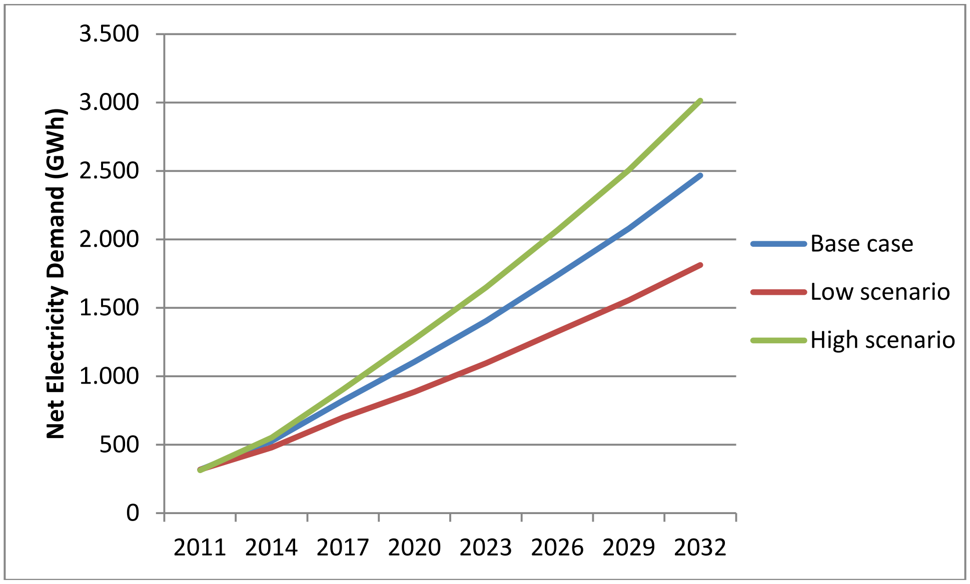


Figure 3.5-9: Development of net electricity demand in the NEPS UZB & NEPS TAJ area

Figure 3.5-10 shows the development of gross energy sent out from power plants and imports for the NEPS UZB & NEPS TAJ area in the period up to 2032. In the base case scenario, this area is forecast to be supplied with 2854 GWh in 2032, while in the same year in the low scenario this would be 2097 GWh and in the high scenario 3487 GWh. This means an average annual growth rate of 9.6% or an increase by a factor of 6.8, which is lower than for net demand, as we assume decreasing levels of losses, as explained earlier.

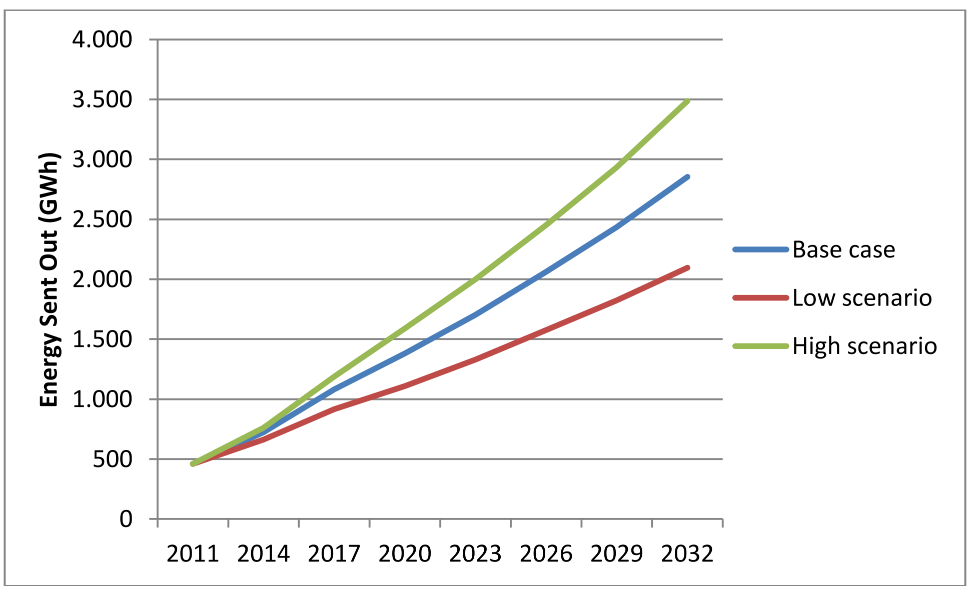


Figure 3.5-10: Development of energy sent out in the NEPS UZB & NEPS TAJ area

Figure 3.5-11 depicts the development of the peak load in the NEPS UZB & NEPS TAJ area. The forecast shows a peak load of 543 MW in this area in 2032 in the base case scenario. In the case of a more favorable development the high scenario would lead to a peak demand of 664 MW, while the low scenario, reflecting a less favorable development, would lead to a peak load of 399 MW. The average annual growth rate of the peak load in this area is 9.6%, so that in total the peak load increases by a factor of 6.8 over the forecasting horizon.

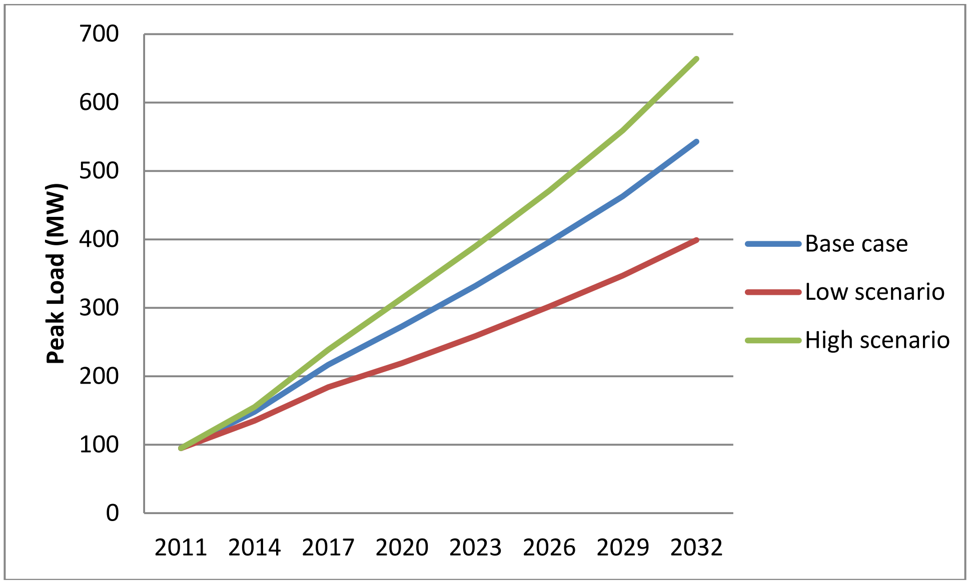


Figure 3.5-11: Development of peak load in the NEPS UZB & NEPS TAJ area

<u>SEPS</u>

As shown in Figure 3.5-12, net electricity demand in the SEPS area (including Helmand and Kandahar) is expected to increase to between 819 GWh (low scenario) and 1276 GWh (high scenario) in 2032, with the base case scenario showing a level of 1068 GWh. The base case scenario for SEPS thus increases by a factor of 8.4 between the current level in 2011 and 2032. This means an average annual growth rate of 10.7%. This factor is considerably higher than Afghanistan as a whole, which results from the fact that the two SEPS provinces currently show comparatively low connection rates and low average household consumption levels.

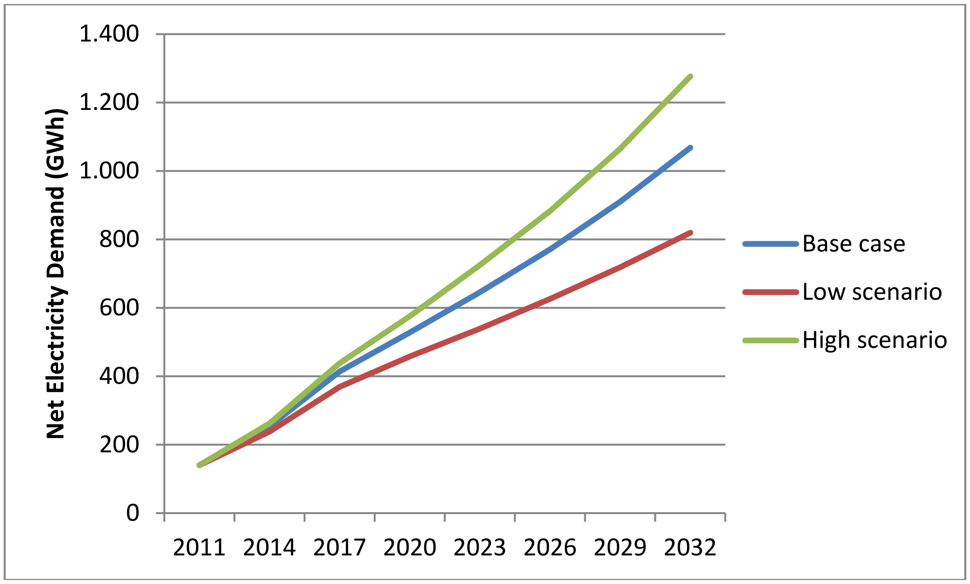


Figure 3.5-12: Development of net electricity demand in the SEPS Area

Figure 3.5-13 shows the development of gross energy sent out from power plants for the SEPS area in the period up to 2032. In the base case scenario, this area is forecast to be supplied with 1236 GWh in 2032, while in the same year in the low scenario this would be 948 GWh and in the high scenario 1476 GWh. This means an average annual growth rate of 9.5% or an increase by a factor of 6.7, which is lower than for net demand, as we assume decreasing levels of losses, as explained earlier.

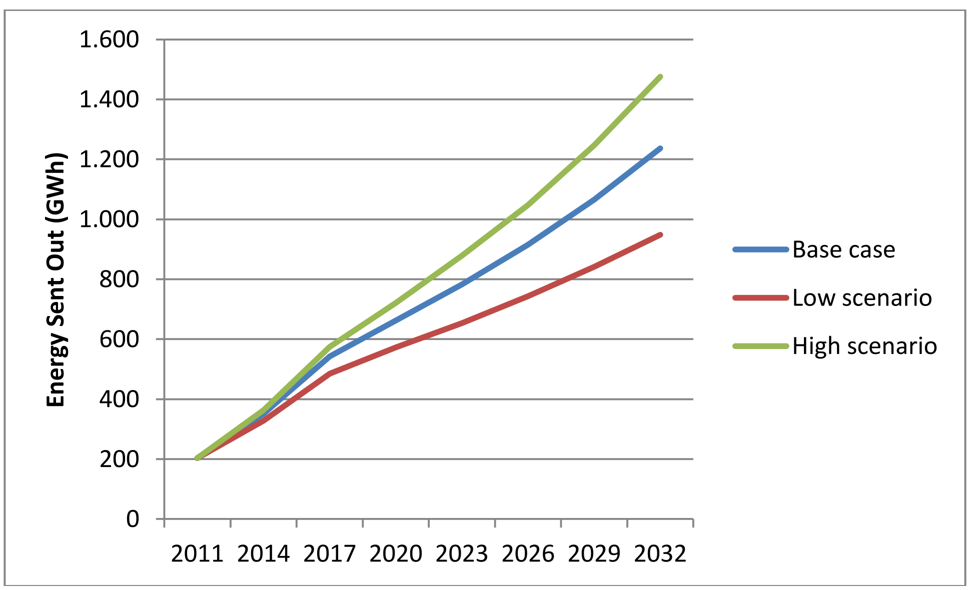


Figure 3.5-13: Development of electricity sent out in the SEPS area

Figure 3.5-14 depicts the development of the peak load in SEPS area. The forecast shows a peak load of 235 MW in this area in 2032 in the base case scenario. In the case of a more favorable development, the high scenario would lead to a peak demand of 281 MW, while the low scenario, reflecting a less favorable development, would lead to a peak load of 180 MW. The average annual growth rate of the peak load in the SEPS area is 9.5%, so that in total the peak load increases by a factor of 6.7 over the forecasting horizon.

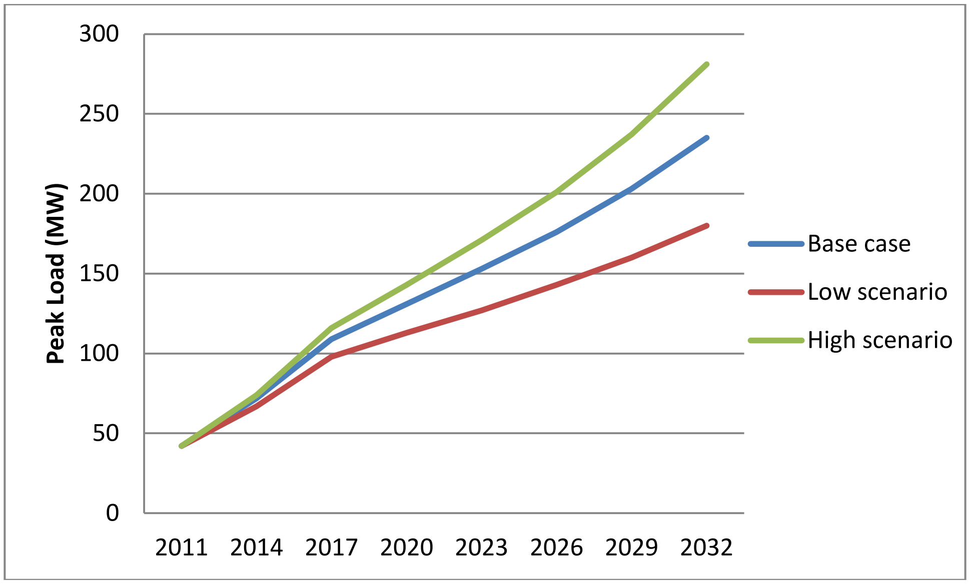


Figure 3.5-14: Development of peak load in the SEPS area

3.6 Additional Load Centers

Beside the Kabul New City Project, two large industrial projects are supported by the Government of Afghanistan. These are mining projects at the Hajigak iron and Aynak copper deposits.

The Kabul New City Project comprises the extension of Kabul into the area north of the city. This is in major parts an extension of the urban residential area. The load forecast methodology considers the population growth and the increase of the connection rate as the basis for load development. Additional residential areas, even if they are concentrated as in the case of Kabul New City, are covered within this methodological approach.

The contract for development of the Aynak copper mine comprises a set of infrastructure measures including construction of a power plant firing coal from the deposits in Samangan and Bamyan provinces. The expected load for the copper mine is 100 MW in the initial phase and increasing to 200 MW in final stage. The power plant has to serve this load and will have to provide an additional amount of generation capacity for feeding to the national grid.

For Hajigak iron mine, the contract has not yet been awarded but it is expected that it will also comprise infrastructure measures, including construction of a power plant firing Afghan coal from the deposits in Samangan and Bamyan provinces. The load forecast for the iron mine is 400 MW and the related power plant has to serve this load and provide the same amount for the national grid. It is expected that the new coal-fired power plants will be located at the coal mine and not at the iron and copper mine.

These additional industrial loads will be handled in addition to the load forecast as discussed above, and the required transmission capacity and network expansion for connecting the mines and the related power plants will be considered within network expansion planning.

3.7 Comparison of Energy Consumption in Afghanistan with other Countries

As discussed with the Afghani authorities and ABD, the results obtained for Afghanistan for future electricity demand are compared with the electricity consumption levels in other countries as a kind of "plausibility check". Such an exercise is not as straightforward as originally thought, mainly due to lack of data on the one hand and structural differences between the various countries with regard to the economic and socio-economic situation on the other. First of all, due to the data situation the comparison can be carried out only at the level of gross electricity demand (i.e. energy sent out from own generation and imports), as no comprehensive and comparable figures are available for net electricity consumption. This means that any differences between the countries in terms of losses (technical and commercial) cannot be taken into account. Secondly, there are widely different levels of industrial activities in the various countries and thus different shares of contribution of the industrial sector to GDP, which is likely to have an impact on the level of electricity consumption. But even if the industrial share in total GDP is the same or similar in two countries, the implications for electricity demand can be completely different, if in one country heavy industry plays a major role while in the other light industry prevails.

There are further differences in the connection rates of residential customers, in electricity requirements for irrigation, in the shares of the various consumer groups in total electricity consumption, in the climatic conditions of a country and numerous other factors that have or may have an impact on electricity consumption.

Foremost, of course, it is the level of economic activity and well-being in a country, usually expressed by the per capita GDP, which has the strongest impact on the level of electricity consumption. In order to allow for this, we compare Afghanistan primarily with countries of a similar level of per capita GDP, but add a number of other countries for specific reasons.

This comparison can be meaningful only if we look at the final result of the forecast for Afghanistan at the end of the forecasting horizon in 2032, and compare these forecast values with the current level of consumption in other countries with a similar level of per capita GDP as Afghanistan in 2032. As the various countries have different population levels, consumption has to be stated per million of population (GWh per one million people) for the countries to be comparable in this regard.

According to the assumptions made in the load forecast for population and economic (GDP) growth rates, the expected GDP per capita in Afghanistan in 2032 is estimated to attain around

US$1200. We therefore obtain the following results for a number of selected countries with similar GDP/capita levels:

Country	**GDP/cap (US$)**	**Electricity consumption (GWh/mln population)**
Afghanistan 2032	1,200	497
Cameroon	1,160	271
Ivory Coast	1,070	225
Ghana	1,240	329
Sudan	1,270	98
Pakistan	1,050	540
India	1,340	717
Laos	1,010	372
Papua New Guinea	1,300	424
Nicaragua	1,080	570

Table 3.7-1: Comparison of GDP/cap and electricity consumption in selected countries

When we look at the results presented in the table, we first recognize that in six of the nine countries, average consumption per population is lower than in Afghanistan, and only in three countries is it higher. This tends to confirm that the figures for Afghanistan are in a reasonable order of magnitude. Of course, lower average electricity consumption for African countries could mainly be explained by differences in climate. The same holds for Laos, despite the fact that we have here a substantially higher share of industry in total GDP.

More interesting, however, is to look at those countries that have a higher consumption per capita. These differences can easily be explained. In Pakistan the average consumption is not much different, less than 10% above the Afghan level, which can be considered to be within the general level of accuracy of the data and forecast instruments. Yet it is worth mentioning that in Pakistan we find more energy-intensive industrial establishments, which can further explain differences. This applies likewise for India. Here the average electricity consumption is about 40% higher, but the figures indicate that a different structure of industrial production plus a higher per capacity income account for this.

We would like to add a comparison for two other countries that have, as far as possible, a similar climate to Afghanistan, namely Bolivia and Nepal. The neighboring countries in Central Asia with a similar climate cannot be taken for comparison as, due to their history, they have completely different electricity systems and consumption patterns. Bolivia shows an electricity consumption level of 661 GWh/mln population. However, as its GDP per capita is about 50% higher (1790 US-$/cap) than the Afghanistan 2032 level and the share of industrial production in total GDP is also more than 50% higher than in Afghanistan, a consumption level corrected by these two factors would lead to the same order of magnitude as Afghanistan. In Nepal, on the other hand, average electricity consumption is only one third of that in Afghanistan in 2032. This is accounted for by a GDP/cap of only 40% of the 2032 Afghanistan level and a lower share of industrial production in total GDP.

The comparison of the future level of consumption of electricity in Afghanistan with other countries, with due consideration of all statistical shortcomings and structural differences between the countries, on the basis of the above considerations and discussion, tends to confirm that the expected order of magnitude of the electricity consumption level in Afghanistan at the end of the forecasting horizon is plausible and reasonable.

3.8 Energy Efficiency and Demand Side Management

Within the context of this Power Sector Master Plan, both Demand Side Management (DSM) and Energy Efficiency (EE) might have an impact on the development of the load forecast.

A distinction must be made between regions with low and high electrification rates. In regions with low electrification rates, most DSM and EE measures will be balanced by an increased number of consumers that are connected to the same generation capacity. In regions with higher connection rates, DSM and EE might actually help to reduce the required generation capacity.

Demand Side Management (DSM)
DSM refers to the reduction of peak loads by shifting consumption from peak to off-peak periods. In general, this can be achieved by shifting consumers that do not have to be operated at a certain point of time to off-peak periods. This can be done either manually or automatically. While in the manual approach, consumers operate their appliances intentionally during off-peak periods, the automatic or smart grid approach requires a signal from the grid that restricts operation of selected appliances. In either case, incentives are essential. The usual approach is to offer different electricity tariffs: a lower tariff for consumers that might be temporarily disconnected and a higher tariff for continuous supply. Another system is based on a so-called high tariff (HT) which is charged during periods with high electricity demand and a low tariff (LT) during off-peak periods. On the basis of the current load profiles for Afghanistan, the period between 6 pm and 10 pm could be defined as the HT period.

The following figure shows a load curve for 23 August [MIN_018]. It is clear that the main peak is in the evening when lights are turned on.

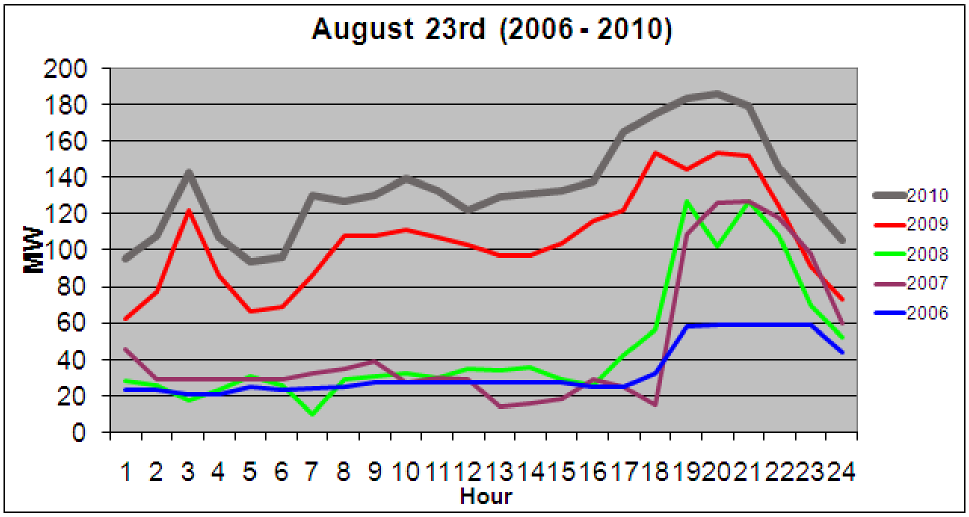


Figure 3.1.4-1: Typical load curve [MIN_018]

Electricity consumption in Afghanistan is dominated by residential consumers, all with a very similar profile. This means that, even for regions with a high connection rate, the introduction of different tariffs as a DSM measure might not have any significant impact on the load profile as people simply require lighting when it is getting dark – they cannot shift this consumption to the LT period.

On the basis of the current customer profile in Afghanistan, the effect of introducing DSM measures on cutting the peaks is very limited. For the load forecast this effect is therefore neglected.

Energy Efficiency (EE)

Energy efficiency in general refers to "using less energy to produce the same amount of goods or services", so adoption of EE can reduce the amount of energy to supply the same services and goods to the same number of consumers. In general, EE programs aim for an individual sector like industry, domestic, transportation or services because these differ significantly in their demand and therefore need different measures. As households account for 70% of electricity consumption, energy conservation mainly focuses on that consumer group. Nevertheless, also the commercial and industrial sectors are taken into account.

Potential measures to reduce electricity consumption in the residential sector are for example:

- replacement of incandescent bulbs by energy saving bulbs: savings of about 30 to 50 kWh per year and bulb
- introduction of energy efficiency labels and reduction of import taxes on energy efficiency products: depending on the appliance, savings of 10–100 kWh per year and appliance
- switch from electrical hot water preparation to solar water heating: savings of about 300–400 kWh per year and person.

Depending on the electrical appliances, EE measures for individual customers might reduce their electricity consumption by 20% to 50%. In reality, increasing prosperity goes hand in hand with a higher penetration of new electrical appliances, like TV sets, washing machines, computers, etc. These new appliances reduce the energy conservation effect of EE measures dramatically – and might even result in an increase of consumption.

Experience in countries with high penetration rates for modern electrical appliances shows that the overall result of taking EE measures is mainly a reduced increase of electricity consumption.

On the basis of the Consultant’s experience for those regions with a high connection rate, it is estimated that adoption of EE measures results in an overall net effect on the electricity consumption development in this specific region of about -1 to -2 percentage points per year.

For regions with low connection rates, the assumption is that EE measures to cut the electricity consumption of individual consumers will be outweighed to 100% by additional customers that can be connected to the grid, so the net effect of EE measures in this case is zero.

4. Assessment of Power Purchase Agreements

In 2011, Afghanistan imported 2250 GWh, amounting to 73% of its overall electrical energy demand. The imports originate from:

- Iran (22%) under 1 contract
- Tajikistan (4%) under 2 contracts
- Turkmenistan (16%) under 2 contracts
- Uzbekistan (57%) under 1 contract.

The following power purchase agreements (PPAs) were provided for review:

Afghanistan - 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)

Afghanistan - Tajikistan:
- Agreement #30/6-BT-MEW on energy supply between Barki Tojik (Tajikistan) and the Ministry of Energy and Water (Islamic Republic of Afghanistan), dated 1382/2003
- Power Purchase and Sale Agreement between Barki Tojik (Tajikistan) and DABM, dated 1387/2008

Afghanistan - 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 the direction of Imamnazar - Andhoi, dated 2002

Afghanistan - Uzbekistan:
- Minutes 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 ongoing power purchase agreement between the Ministry of Energy and Water and Uzbekenergo is still outstanding.

Assessments of these agreements are provided in the following sections.

4.1 PPA with Iran

The "Agreement for Construction of Transmission Line and Power Purchase" was signed between MEW and the Ministry of Energy of the Islamic Republic of Iran in January 2003 (1388). The PPA had a duration of four years until March 2007. In January 2010 the agreement was extended retroactively by another nine years until 2015 (1394).

The PPA covers imports via:

- the 132 kV line from Taibat to Herat
- the 20 kV line from Turbat-e-Jam SS to Herat and
- the 20 kV line from Zohak SS/Zabul to Zaranj.

The PPA provides for an annual supply of 200 ± 5 GWh with a maximum capacity of 90 MW. It is intended to increase the supply of 90 MW by 60 MW to 150 MW. The agreement is expected to be signed in mid-2012.

The 20 kV line from Zabul SS to Zaranj has a maximum capacity of 10 MW.

The import tariff is 4.0 cents/kWh, of which 3.0 cents are to be paid by DABS and 1.0 cent is drawn from the Iran Aid to Afghanistan. The tariff to be paid by DABS will remain at 3.0 cents/kWh, even if Iran Aid is discontinued.

A new 132 kV transmission line from Iran SS to Farah is in the planning stage. It is intended to increase the supply via the new line step-wise, similar to the imports via the existing 132 kV line. The conditions of the existing PPA would also apply to the new line.

4.2 PPA with Tajikistan

The "Agreement #30/6-BT-MEW on energy supply" was signed between Barki Tojik (Tajikistan) and the MEW in December 2003. It governs imports via the 110 kV line from Geran SS (Tajikistan) to Kunduz SS.

The PPA was originally concluded for a period of six years until December 2009, but it was extended for another five years up to 2014. It does not provide for firm energy deliveries. The delivery schedule is to be agreed between the parties. The tariff is fixed at 2.0 cents/kWh over the term of the PPA.

Another PPA governs imports from Sangtuda HPP in Tajikistan via the double circuit 220 kV line linking Sangtuda SS and Kunduz SS. The "Power Purchase and Sale Agreement" between Barki Tojik (Tajikistan) and DABM, the predecessor of DABS, was signed in August 2008 (1387) for a period of 20 years. Phase I of the PPA started in April 2010. Phase II will start in May 2015.

The firm delivery schedule is agreed on a monthly basis for the years 2010 to 2014. Imports are limited to the summer months from April to October; the total contractually agreed imports are set to increase from 500 GWh in 2010 to 651 GWh in 2014. The PPA also provides daily and hourly firm energy schedules.

The PPA does not provide for firm imports from November to March, but since commissioning of Sangtuda HPP, Barki Tojik has supplied approx. 10 MW non-firm energy in winter; an increase of this supply to 60 MW is currently under negotiation.

The annual delivery schedule for Phase II starting in 2015 will be confirmed in 2013, depending on the additional generation and transmission assets to be constructed.

The tariff to be paid for firm, non-firm, testing and unscheduled energy is 3.5 cents/kWh in 2010. This tariff will be increased by 2% annually during Phase I; the escalation will continue in Phase II unless otherwise agreed.

In case of under-delivery of firm energy, Barki Tojik has to pay a penalty, provided that during a six-month period less than 85% of the committed energy was delivered. Likewise DABS has to pay a penalty for under-acceptance when less than 85% of the committed firm energy was accepted. The penalty increases from 100% of the tariff in 2010 to 104% of the tariff from 2012 onwards.

4.3 PPA with Turkmenistan

In 2002, the MEW and the Ministry of Energy and Industry of Turkmenistan signed two PPAs for energy imports via 110 kV transmission lines:

- KEN - 02/03 for supply from Zernow SS in Turkmenistan to Andkhoy
- KEN - 02/04 for supply from Mary SS in Turkmenistan to Tourgundi and Herat.

Both PPAs have similar conditions. They are extended annually; the amendments lay down the annual energy to be supplied as well as the price. From 2002 to 2011, the tariff had been 2.0 cents/kWh. In 2012 it was increased to 2.8 cents/kWh. The 7th amendment to the PPA for the supply of Andkhoy (KEN - 02/03) provides for supply of 200 GWh in 2012; the committed energy for the supply of Tourgundi (KEN - 02/04) is not known to the Consultant.

The tender for an upgrade of the transmission line from Mary SS to Tourgundi and Herat (220 kV) is currently being prepared. The principles of the PPA KEN 02/04 will also apply to imports via this line, but the tariff has still to be renegotiated; it is expected to be at least 3.0 cents/kWh.

4.4 PPA with Uzbekistan

Afghanistan has a PPA with Uzbekenergo for supply from Surkhan SS (Uzbekistan) to Hairatan (Afghanistan). The PPA has not been made available to the Consultant. According to verbal information from DABS, Uzbekistan currently provides 500 GWh of firm energy per year. It is intended to increase the supply to 800 GWh and 1200 GWh in 2012.

The import tariff is 6.0 cents/kWh. If DABS accepts less than the agreed energy minus 10%, it has to pay a penalty of 7.5 cents (equivalent to 125% of the tariff) for the difference; if Uzbekistan supplies less than the agreed energy minus 10%, it has to pay a similar penalty for the shortfall.

A new PPA has to be agreed between MEW and Uzbekenergo when the 110 kV line from Amu SS (Uzbekistan) to Hairatan (Afghanistan) is re-energized, as it is currently out of operation. The tariff for the supply of approximately 80 MW still has to be negotiated, it is assumed to be between 6.0 and 7.0 cents/kWh.

4.5 Summary and Conclusions

Assessment of the PPA was carried out based on the documents made available during data collection phase in first quarter of 2012. It was mentioned by MEW during discussion on the first draft of the Master Plan Report 11th and 12th February 2013 that new PPA with Uzbekistan and Iran were executed in December 2012. DABS were asked to provide the new PPA for assessment by Fichtner. Unfortunately the documents were not provided DABS and an updated with the new figures according the latest PPA was not possible.

The key features of the existing PPAs are summarized in the table below.

Country	Contract term (from – extended – to)	Supply	Tariff (US cents/kWh)
Iran	2003 – 2007 – 2015	Firm	3.0
Tajikistan 110 kV 220 kV from Sangtuda HPP	 2003 – 2009 – 2015 Phase I: 2010 – 2015 Phase II: 2015 - 2030	 Non-firm Firm (summer only)	 2.0 Ph. I: 3.5 Ph. II: to be negotiated
Turkmenistan 2 separate but similar contracts	2002 – annual amendments	Firm	2.8
Uzbekistan	n.a.	Firm	6.0

Table 3.1.4-1: Key features of the power purchase agreements

As a comment on the first draft of the master plan

Assessment of the PPAs leads to the following conclusions:

- All contracts except with hydro-dominated Tajikistan provide year-round firm energy.
- Tariffs range from 2.0 to 6.0 cents/kWh. Imports from Uzbekistan, which has the highest share in imports, are the most expensive.
  The tariffs for planned imports from Turkmenistan and Uzbekistan will be higher than the existing ones.
- All contracts except the PPA with Tajikistan have a short duration and thus provide little supply security.

Short term plans for new contracts concern imports:

- from Mary SS (Turkmenistan) to Herat (Afghanistan) via the upgraded 220 kV line (currently in the tender phase)
- from Amu SS (Uzbekistan) to Hairatan (Afghanistan) via the re-energized 110 kV line (currently under negotiation)
- from Atamyrat SS (Turkmenistan) to Andkhoy SS (Afghanistan) via a new 500 kV line (project is currently in the funding phase).

5. Present Status of Power System

The Islamic Republic of Afghanistan is divided into 34 provinces. ISO 3166-2 codes are defined for these as shown in the following table. These provinces are numbered in the report in the order of their names in the Latin alphabet.

No.	Code* AF-	Name*	Name**	Center	Population in 2011	Area (km²)
1	BDS	Badakhshān	Badakhshan	Fayzabad	889,700	44,059
2	BDG	Badghīs	Badghis	Qala i Naw	464,100	20,591
3	BGL	Baghlān	Baghlan	Puli Khumri	848,500	21,118
4	BAL	Balkh	Balkh	Mazari Sharif	1,219,200	17,249
5	BAM	Bāmyān	Bamyan	Bamiyan	418,500	14,175
6	DAY	Dāykundī	Daykundi	Nili	431,300	8,088
7	FRA	Farāh	Farah	Farah	474,300	48,471
8	FYB	Fāryāb	Faryab	Maymana	931,800	20,293
9	GHA	Ghaznī	Ghazni	Ghazni	1,149,400	22,915
10	GHO	Ghōr	Ghor	Chaghcharan	646,300	36,479
11	HEL	Helmand	Helmand	Lashkar Gah	864,600	58,584
12	HER	Herāt	Herat	Herat	1,744,700	54,778
13	JOW	Jowzjān	Jowzjan	Sheberghan	503,100	11,798
14	KAB	Kabul	Kabul	Kabul	3,818,700	4,462
15	KAN	Kandahār	Kandahar	Kandahar	1,127,000	54,022
16	KAP	Kapīsā	Kapisa	Mahmud-i-Raqi	413,000	1,842
17	KHO	Khōst	Khost	Khost	537,800	4,152
18	KNR	Kunar	Kunar	Asadabad	421,700	4,942
19	KDZ	Kunduz	Kunduz	Kunduz	935,600	8,040
20	LAG	Laghmān	Laghman	Mihtarlam	417,200	3,843
21	LOG	Lōgar	Logar	Pul-i-Alam	367,000	3,880
22	NAN	Nangarhār	Nangarhar	Jalalabad	1,409,600	7,727
23	NIM	Nīmrōz	Nimruz	Zaranj	153,900	41,005
24	NUR	Nūristān	Nuristan	Parun	138,600	9,225
25	PIA	Paktiyā	Paktia	Gardez	407,100	19,482
26	PKA	Paktikā	Paktika	Sharan	516,300	6,432
27	PAN	Panjshayr	Panjshir	Bazarak	143,700	3,610
28	PAR	Parwān	Parwan	Charikar	620,900	5,974
29	SAM	Samangān	Samangan	Aybak	362,500	11,262
30	SAR	Sar-e Pul	Sar-e Pol	Sar-e Pol	522,900	16,360
31	TAK	Takhār	Takhar	Taloqan	917,700	12,333
32	URU	Uruzgān	Uruzgan	Tarin Kowt	328,000	22,696
33	WAR	Wardak	Wardak	Meydan Shahr	558,400	9,934
34	ZAB	Zābul	Zabul	Qalat	284,600	17,343
			Total		24,987,700	647,164

* According to ISO 3166-2 standard published by the ISO 3166 Maintenance Agency (ISO 3166/MA).

** used in the Report

Table 5.0-1: List of provinces in Afghanistan according to the ISO 3166-2 standard

Under the ISO standard, special letters are used for the vowels ā, ī, ō, ū. To simplify typing in the report, we use the Latin letters for the vowels.

A map prepared by USAID [AEIC_008] showing the provinces is given in **Annex 5.0-1**. There are slight differences in numbering between USAID documentation and the latest ISO 3166-2 standard, and the map has been adapted accordingly.

Historical development of population

The historical development of population within the 34 provinces was given within the Afghanistan CSO population data book, prepared by USAID [AEIC_003] for the years from 1996 to 2011. This document gives details of the population on province level. Within the provinces, the population center is also stated.

The following table shows the development of population in Afghanistan over the last fifteen years.

Year	Population in (000)	Annual increase
1996	18515.2	
1997	18439.3	-0.4%
1998	18797.0	1.9%
1999	18597.6	-1.1%
2000	19532.7	5.0%
2001	20093.0	2.9%
2002	20297.5	1.0%
2003	20397.4	0.5%
2004	21677.7	6.3%
2005	22098.8	1.9%
2006	22576.1	2.2%
2007	23042.9	2.1%
2008	23511.4	2.0%
2009	23993.5	2.1%
2010	24485.6	2.1%
2011	24987.7	2.1%

Table 5.0-2: Historical development of the population of Afghanistan

Details of the population on province level are given in **Annex 5.0-2**, which shows the development of total population of the provinces as a total of both sexes in thousands. The source for this summary is the population data on district level as published since 2010 by the Afghanistan Central Statistics Organization (CSO) [OS_072 and OS_073].

Historical development of power generation

Power generation in Afghanistan is mainly hydro based and this slightly increased in the past. Thermal generation has reduced in the last three years and, in total, local generation has remained constant in the range of 800 to 1000 GWh.

The rapid increase of consumption has been driven by the availability of additional imports, amounting to about 73% in 2011, which is high compared with the share of 34% in 2006. The generation and import figures as summarized in the table below are taken from the AEIC Annual Production Reports.

Year	2006	2007	2008	2009	2010	2011
Hydro [GWh]	644	755	617	835	910	801
Thermal GWh]	213	211	197	93	101	39
Import [GWh]	432	609	752	1,155	1,572	2,246
Total [GWh]	1,289	1,575	1,566	2,083	2,583	3,086

Table 5.0-3: Historical development of power production and imports in Afghanistan

Within the annual production reports for 2010 and 2011, parts of the monthly production of the thermal power plants in Kabul and in the south area are missing or incomplete, so thermal generation could be slightly higher than stated in the above table.

Historical development of connection rate

The numbers of DABS customers throughout Afghanistan since 2003 are compiled from various sources. Figures are obtainable from the presentation of DABS held during the inception meeting in January 2012 in Stuttgart [DABS_002], the DABS Customer Database update 18.06.2011 [DABS_005] and the presentation to the ICE Committee on 29 January 2012 “Overview of DABS Accomplishments and Priorities” [DABS_011]

The following table shows the number of customers since 2003 taken from the various sources.

Year	Number of customers according to different sources			Increase %
	DABS_002	DABS_011	DABS_005	
2003			**227854**	
2004			**277667**	21.9
2005			**410027**	47.7
2006			**432606**	5.5
2007	599014	**599014**	551262	38.5
2008	633029	**633029**	648291	5.6
2009	746822	**746822**	685521	18.0
2010	786449	**786449**	786302	5.4
2011	827465	**841376**		7.0

Table 5.0-4: Development of numbers of DABS consumers

The number of customers since 2003 shows an impressive increase year by year. The bold type numbers were used for calculating this increase.

The share of population with access to DABS electricity within the different provinces varies over a wide range depending on population density, the availability of power transmission facilities and geographic conditions.

The detailed results of the analysis of the statistics on province level for 2010 and 2011 are given in **Annex 5.0-3** and **Annex 5.0-4**.

For 2010, the total population of Afghanistan was 24.5 million in rural and urban regions. The persons per household are estimated on average as ten and six for rural and urban regions respectively. Analysis of data for 2010 leads to an average connection rate of 24%. A similar calculation for 2011 with a total population of about 25 million leads to an average connection rate of 28%.

For this analysis, it has to be pointed out that the detailed statistics on customers per province from DABS for 2010 and 2011 indicate a total number in 2010 of 682,454 customers and in 2011 of 809,335 customers, which are less than the figures given in the table above.

Quality of power supply
DABS reports high voltage drops along the import lines, especially from Turkmenistan and Iran.

Measurements at substations in the northwest show dramatic voltage drops during high load periods. Examples of voltage and load measurements taken on 26 February 2012 at the 35 kV busbar at Sheberghan are shown in the following table. The voltage drops from 32 kV during the night to 16.5 kV and 18 kV during peak loads in the morning and evening hours.

Hour	Measured values		Calculated active power	
	U [kV]	I [A]	P_L* [MW]	P_N** [MW]
1	30	180	7.94	9.03
2	30	185	8.16	9.29
3	29	195	8.32	10.13
4	29	200	8.53	10.38
5	26	205	7.84	11.87
6	19	170	4.75	13.47
7	16.5	180	4.37	16.43
8	16.5	180	4.37	16.43
9	18	190	5.03	15.89
10	19.5	170	4.87	13.13
11	20	180	5.29	13.55
12	20	180	5.29	13.55
13	21	190	5.87	13.62
14	25	172	6.32	10.36
15	22	205	6.63	14.03
16	19.5	180	5.16	13.90
17	19.5	205	5.88	15.83
18	20	200	5.88	15.06
19	20	200	5.88	15.06
20	17.5	205	5.28	17.64
21	18	210	5.56	17.57
22	18	210	5.56	17.57
23	23	208	7.03	13.62
24	32	180	8.47	8.47

* Low voltage considering a power factor of 0.85
** Estimated power expected for a proper voltage of 30 kV

Table 5.0-5: Measurements of voltage and load taken on 26 February 2012 at the 35 kV busbar at Sheberghan

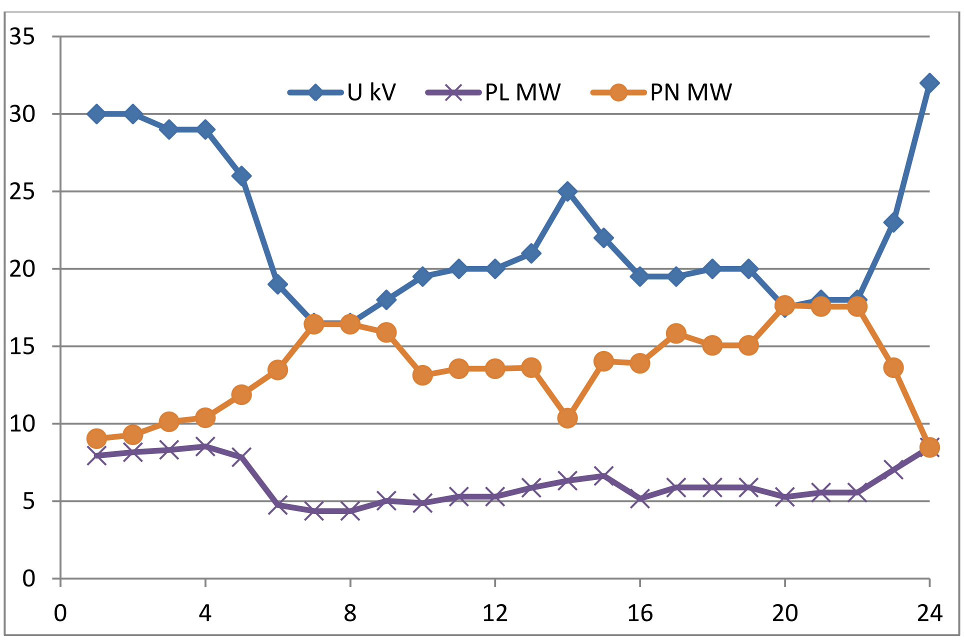


Figure 5.0-1: Load curve for Sheberghan measured on 26 February 2012 with a high voltage drop

The load curve calculated from the measurements did not show a typical load curve for an area dominated by a residential load. The load curve for the estimated power expected for normal voltage shows the well known shape for residential loads. Comparison of the two load curves reveals high uncertainties in the data for current consumption within the network portions in Afghanistan with low and unstable voltage conditions.

Regions supplied by DABS
The average connection rate in Afghanistan is about 28%, which varies over a wide range for the different provinces depending on population density, settlement pattern and location in relation to import possibilities and large generator plants.

The Afghan transmission system is divided into different grid segments according to their source of supply. A description is given in section 5.3.3.

Besides grid-connected consumers, there are many off-grid networks based on micro hydro, small diesel units or renewable energy sources operated in Afghanistan's rural regions.

5.1 Existing Power Generation

5.1.1 Hydro power plants

Local generation in Afghanistan is dominated by hydro power plants. In the following, existing power plants are listed with brief descriptions of the main ones (**Annex 5.1.1-1**).

Name	River	Capacity after rehabilitation [MW]	Date of commissioning / rehabilitation	Annual energy** [GWh]	Estimated costs *** [$m]
Naghlu	Kabul	100	1967 / mid 2013	413	90
Sarobi	Kabul	22	1957 / completed	188	25
Mahipar	Kabul	66	1967 / completed	152	80
Darunta	Kabul	11.5	1964 / 2012	85	14
Assassab.	Kunar	0.7	1983 / *	4	1.2
Charikar	Ghorband	2.4	1973 / *	14	3.6
Jabul Ser.	Salang	2.5	1920 / *	14	3.6
Ghorband	Ghorband	0.3	1975 / *	2	0.6
Kajaki (I & III)	Helmand	33	1975 / completed	272	40
Grishk	Helmand	2.4	1957 / *	14	3.6
Pul-i-Chomri	Pulikhumri	3x1.37=4.12	1950 / 2013-2015	24	6
Pul-i-Chomri II	Pulikhumri	3x2.93=8.79	1962 / 2013-2015	49	13

* It assumed that rehabilitation is required

** generation after rehabilitation

*** for the next rehabilitation

Table 5.1.1-1: Existing hydro power plants

Naghlu HPP
Naghlu Hydropower Plant is located on the Kabul River in the eastern region of Afghanistan. It was commissioned in 1967. The equipment is Russian. It has a reservoir dammed up by a concrete gravity wall. Due to the small reservoir capacity and high inflow, reservoir operation is limited, so operation is comparable with run-of-river plants. The head is 64 m and installed capacity is 4x25 MW.

It is expected that all units will be rehabilitated by autumn 2012.The lifetime of the electromechanical equipment is estimated to be about 25 years and the costs for rehabilitation are approximately 30% of the construction costs of a new plant. The construction costs are estimated at about 300 million US$, so rehabilitation costs will be approximately 90 million US$. The start of the next rehabilitation is assumed to be in 2035.

Sarobi HPP
Sarobi Hydropower Plant is located on the Kabul River in the eastern region of Afghanistan. It was commissioned in 1957. The original equipment is German. It is operated as a run-of-river plant. The installed capacity is 2x11 MW.

All units were rehabilitated recently. Taking into account that the lifetime of the electromechanical equipment is estimated to be about 25 years and the costs for rehabilitation are approximately 30% of the construction costs of a new plant, rehabilitation costs will be approximately 25 million US$ based on construction costs of 84 million US$. The start of the next rehabilitation is assumed to be in 2032.

Mahipar HPP
Mahipar Hydropower Plant is located on the Kabul River in the eastern region of Afghanistan. It was commissioned in 1967. It is operated as a run-of-river plant. The installed capacity is 3x22 MW.

All units were rehabilitated recently. We consider the lifetime of the electromechanical equipment to be about 25 years and the costs for rehabilitation to be around 30% of the construction costs of a new plant, so rehabilitation costs will be approximately 80 million US$, based on construction costs of about 260 million US$. The start of the next rehabilitation is assumed in 2032.

Darunta HPP
Darunta Hydropower Plant is located on the Kabul River in the eastern region of Afghanistan. It was commissioned in 1964. The installed capacity is 3x3.85 MW.

It is expected that all units will be rehabilitated by autumn 2012. The lifetime of the electromechanical equipment is estimated to be about 25 years and the costs for rehabilitation are approximately 30% of the construction costs of a new plant. The construction costs are estimated at about 45 million US$, so the rehabilitation costs will be approximately 14 million US$. The start of the next rehabilitation is assumed to be in 2035.

Assassabad HPP
Assassabad Hydropower Plant is located on the Kunar River in the eastern region of Afghanistan. It was commissioned in 1983. The original installed capacity is 2x0.35 MW.

No information is provided on the condition of the plant and rehabilitation measures but it is assumed that rehabilitation is required. The construction costs are estimated at about 4 million US$, so the rehabilitation costs will be approximately 1.2 million US$, based on the approximation of 30% of construction costs for a new plant.

Charikar HPP
Charikar Hydropower Plant is located on the Ghorband River in the northern region of Afghanistan. It was commissioned in 1973. The original installed capacity is 3x0.8 MW.

No information is provided on the condition of the plant and rehabilitation measures but it is assumed that rehabilitation is required. The construction costs are estimated at about 12 million US$, so the rehabilitation costs will be approximately 3.6 million US$, based on the same assumption as for the previous power plants.

Jabul HPP
Jabul Hydropower Plant is located on the Salang River in the northern region of Afghanistan. It was commissioned in 1920. The original installed capacity is 2x0.5 + 2*0.7 = 2.5 MW.

No information is provided on the condition of the plant and rehabilitation measures but it is assumed that rehabilitation is required. The construction costs are estimated at about 12 million US$. The rehabilitation costs will be approximately 3.6 million US$, based on the assumption for rehabilitation costs of approximately 30% of construction costs.

Ghorband HPP
Ghorband Hydropower Plant is located on the Ghorband River in the northern region of Afghanistan. It was commissioned in 1975. The original installed capacity is 3x0.1 MW.

No information is provided on the condition of the plant and rehabilitation measures but it is assumed that rehabilitation is required. The construction costs are estimated about 2 million US$. The rehabilitation costs will be approximately 0.6 million US$ based on the same assumption as above.

Kajaki I & III HPP
Kajaki Hydropower Plants I & III are located on the Helmand River in the southern region of Afghanistan. It was commissioned in 1975. The original equipment is American. The installed capacity is 2x16.5 MW.

All units were rehabilitated recently. The construction costs are estimated at about 135 million US$, so the rehabilitation costs will be approximately 40 million US$. The start of the next rehabilitation is assumed to be in 2035, based on the same assumptions as above.

Grishk HPP
Grishk Hydropower Plant is located on the Helmand River in the southern region of Afghanistan. It was commissioned in 1957. The original installed capacity 2x1.2 MW.

No information is provided on the condition of the plant and rehabilitation measures but it is assumed that rehabilitation is required. The construction costs are estimated at about 12 million US$. The rehabilitation costs will be approximately 3.6 million US$, based on the assumption for rehabilitation costs of approximately 30% of construction costs.

Pul-e-Chomri I HPP
Pul-e-Chomri Hydropower Plant I is located on the Kunduz River in the northern region of Afghanistan. It was commissioned in 1950. The original equipment is German. The installed capacity is 3x1.6 MW.

The plant and the weir need rehabilitation. Rehabilitation, funded by KfW, is scheduled from 2013 to 2015. The next rehabilitation is expected in 2040, as the lifetime of the electromechanical equipment is estimated to be about 25 years. The costs for rehabilitation are approximately 30% of the construction costs of a new plant, which are estimated at about 20 million US$, so rehabilitation costs will be approximately 6 million US$.

Pul-e-Chomri II HPP
Pul-e-Chomri Hydropower Plant II is located on the Kunduz River in the northern region of Afghanistan. It was commissioned in 1962. The original equipment is Russian. The installed capacity is 3x3.5 MW.

The plant needs rehabilitation. The rehabilitation, funded by KfW, is scheduled from 2013 to 2015. The next rehabilitation is expected to start in 2040. The construction costs are estimated at about 42 million US$, so rehabilitation costs will be approximately 13 million US$, based on the same cost approximation as assumed above.

5.1.2 Thermal power plants

All the existing thermal power plants of Afghanistan are fired by imported diesel fuel. Nearly all of this thermal generation comes from reciprocating engines with the exception of the Kabul NE power plant, which consists of two diesel-fired gas turbines.

The technical reasons for this situation are:

- the electrical grid coverage is very low
- diesel generators can be installed virtually anywhere
- CAPEX for diesel gensets for small capacity power supply is comparatively low
- diesel fuel can be transported
- the technical complexity is low.

The main disadvantage of diesel gensets is the cost for fuel that has to be imported at international prices. A calculation of the costs of electricity generated by diesel gensets is given in section 6.1.2.8.

A list of existing diesel-fired power plants is given in Table 5.1.2-1.

Site	Type	Net efficiency	Capacity MW	CAPEX 000 $	Grid segment
NW Kabul, GT3	GT	24%	21.8		Kabul
NW Kabul, GT4	GT	24%	23.0		Kabul
Tarakhil	RE	39%	105.0	126,000	Kabul
Nangarhar	RE	39%	2.7	3,240	Kabul
Aybak	RE	39%	1.8	2,160	off grid
Taleqan	RE	39%	1.4	1,680	off grid
Ghazni	RE	39%	1.7	2,040	off grid
Kandahar KTA50	RE	39%	11.9	14,280	Kandahar
Kandahar KTA50 exp.	RE	39%	12.0	14,400	Kandahar
Kandahar QSK60	RE	39%	8.8	10,560	Kandahar
Kandahar USACE	RE	39%	20.0	24,000	Kandahar
Khost	RE	39%	1.1	1,320	off grid
Lashkar Gah / Helmand	RE	39%	3.8	4,560	Kandahar
Musa Qala	RE	39%	0.9	1,080	off grid
Paktiya	RE	39%	1.8	2,160	off grid
Qalat/Zabol	RE	39%	2.6	3,120	off grid
Tirin Kot/Uruzgan	RE	39%	0.9	1,080	off grid

GT gas turbines
RE reciprocating engines

Table 5.1.2-1: Existing diesel-fired power plants

5.1.3 Renewable energy

Local generation from renewable energy in Afghanistan is dominated by hydro power plants, as listed in section. 5.1.1. Currently, no other renewable energy sources contribute to on-grid power generation in Afghanistan.

In the following, the few ongoing projects for renewable energy power plants other than hydro power are described. A distinction is made between biomass, geothermal energy, solar and wind.

Biomass
Very little information on the use of biomass for energy recovery is available for Afghanistan. According to the "Afghan Rural Renewable Energy Strategy" presented by the MEW and the MRRD, currently 85% of Afghan energy demand is met by biomass **[MIN_006]**. This is solid biomass that is mainly used for heating and cooking. In addition, there are minor biogas-to-heat projects in the south of Afghanistan.

No information on electricity generation from any kind of biomass – solid, gaseous or liquid – is presented in the available data. There is also no study on biomass or its potential for Afghanistan in particular.

On the basis of the available information, it may be concluded that at present there is no power generation from biomass in Afghanistan.

Geothermal

On the basis of the available information, it can be concluded that there is no geothermal power generation in Afghanistan.

Solar

The current status of solar power generation in Afghanistan is that there are no large-scale solar power plants in operation or in planning that could contribute to the on-grid electricity supply.

There are several small-scale off-grid PV projects in operation, under construction and in planning. According to the "Energy Sector Status Report, July - September 2011" presented by the ICE **[MIN_001]**, the entire installed capacity in Afghanistan is some 6.7 MW. It is not certain that these projects equating to 6.7 MW are available and currently generating electricity because, according to a comment on our Interim Report, many small renewable energy projects (probably mostly photovoltaic projects) were constructed at various places in Afghanistan over the past decade. But only after brief operating periods (the comment talks about "a few months"), generation ceased and today most of these systems are out of service.

According to Renewable Energy Department recent survey Afghanistan's installed capacity of Solar projects are about 12.8 MW and further 1.5 MW is under construction.

Several projects are ongoing or in planning by several donors and institutions, some of which are listed below.

NSP – Installation of small PV systems ranging from 20–40 W. According to the "Afghan Rural Renewable Energy Strategy" (**[MIN_006]**), about 103 kW of capacity in total has been installed up to now. Hybrid systems of a larger scale are under development. [**OS_038]**

Government of New Zealand – Development of a 1 MW solar system to support an installed diesel generator in Bamyan province **[OS_042 and OS_046]**.

World Bank – Afghanistan Rural Solar Electrification of the provinces Bamyan and Daikundi [**OS_042]**.

Wind

Currently there is almost no wind turbine generation in operation in Afghanistan. Only the Pandshir small wind farm is mentioned in the provided documents, which operates ten wind turbines of 10 kW each.

5.2 Present Power Imports

Currently there are five transmission lines used for power import which feed into NEPS from Turkmenistan, Uzbekistan and Tajikistan. Three lines import power from Iran. None of these import sources are interconnected to other power systems.

Exporting	Exporting substation	via	Importing substation	Importing province
Iran	Zohak	-	Zaranj	Nimruz
Iran	Turbat-i-Jam	Islam Qala	Kohshan	Herat
Iran	Taibat	Islam Qala	Mir Dawod	Herat
Tajikistan	Geran	Shirkhanbandar	Kunduz	Kunduz
Tajikistan	Sangtuda	Shirkhanbandar	Pul-e-Chomri	Baghlan
Turkmenistan	Mary	Tourgundi	Noor Jahad	Herat
Turkmenistan	Zernow	Aqeena	Andkhoy	Faryab
Uzbekistan	Surkhan	Hayratan	Naibabad	Balkh
Uzbekistan	Amu	Hayratan	Mazar-e-Sharif*	Balkh

* Line currently not energized

Table 5.1.3-1: Import lines as of February 2012

Most import lines are currently operated at their maximum capacity. The reported voltage profile at the receiving end indicates that the limit of voltage stability has been reached for the import lines.

5.3 Existing Transmission System

The following focuses on high voltage level assets needed for HV long distance transmission and integration of generation. As agreed, the following excludes assets of medium and lower voltage levels needed for local power distribution, unless these are relevant.

5.3.1 Considered main assets

Consequently, the considered transmission system assets are:

- transmission lines with rated voltages of at least 110 kV
- on-grid generators
- substations with maximum rated voltages of at least 110 kV and substation-related equipment like:
  - busbars with rated voltages of at least 110 kV
  - transformers with rated primary voltages of at least 110 kV
- compensation equipment at a rated voltage of at least 110 kV.

5.3.2 Information sources

Sources for compiling a consistent data baseline are summarized in the following table:

Description	Source label according to Annex 2.7.2-1
Ministry of Economy and Inter-Ministerial Commission for Energy: Energy Sector Status Report, July – September, 2011.	[MIN_001] pg 9f, 82, 83
USAID : Transmission data book, October / November 2011.	[AEIC_23] [AEIC_24]
USAID: Substation data book, November 2011.	[AEIC_25] sh*. 'Existing'
DABS presentation at Inception Meeting, Stuttgart, 23rd - 27 January 2012.	[DABS_002]
Fichtner local team: SLD of NEPS substations, February 2012.	[OS_071]
Fichtner local team: SLD of afghan substations, February 2012.	[OS_58]
Fichtner: List of existing HPPs and candidates.	-

* sh: Microsoft Excel 2007 sheet

Table 5.3.2-1: List of sources used for setting up the data base

Assets that are funded and currently under construction (according to [MIN_001]) are referred to as ‘existing’.

5.3.3 Power system areas

The existing power system of Afghanistan is operated in islanded areas depending on the source of generation and imports.

The breakdown of NEPS into different systems reflects the current asynchronous operation mode that results from disconnection of Mazar-E-Sharif and Sheberghan, and the separate in-feed from Tajikistan to the Kunduz area. The Kabul area is divided into a part served by local Afghan generation and a portion connected to the Uzbek system via the Salang Pass 220 kV line. Because the existing connection via the Salang Pass is currently a bottleneck for the Afghan system served from Uzbekistan, the segments north and south of the Salang Pass are considered as separate systems.

A map showing the existing system and network segmentation is given in **Annex 5.3.3-1**.

Segment	Province		
NEPS TKM	Faryab	Jowzjan	Sar-e Pol
NEPS UZB	Parwan	Samangan	
NEPS Kabul UZB	Kabul, partly		
NEPS TAJ	Baghlan	Balkh	Kunduz
NEPS AFG	Kabul, partly	Laghman	Logar

Segment	Province		
	Nangarhar	Paktia	Takhar
Herat TKM	Herat, partly		
Herat IRAN	Herat, partly		
Herat AFG	Herat, partly		
Nimruz IRAN	Nimruz		
SEPS	Helmand	Kandahar	

Table 5.3.3-1: Power system segments and respective provinces, June 2012

- The power systems of Tajikistan, Uzbekistan and Turkmenistan operate asynchronously. Without a means for synchronization or using back-to-back stations, it is not possible to establish a unified Afghan power grid. Separation of the NEPSs into the following subsystems results from this rigid condition.
  1. NEPS TKM
  2. NEPS UZB / NEPS Kabul UZB
  3. NEPS TAJ
  4. NEPS AFG

- All substations in NEPS TKM including Sheberghan are connected to the Turkmen power system via the Zernow(TKM) - Aqeena (AFG) - Andkhoy (AFG) tie-in.
- All NEPS UZB substations are connected to the Uzbek substation at Surkhan via Hayratan. The Uzbek power system is thus connected to the Kabul system via the Pul-e-Chomri - Chimtala line.
- Kunduz is connected to the Tajik substations at Geran and Sangtuda via Shirkhanbandar. The currently Tajik-fed grid segment accounts for the NEPS TAJ supply and it also shares assets for the Uzbek in-feed at a common connection point at Pul-e-Chomri.
- The new 220 kV substation Kunduz 2 will connect to the Tajik Afghan interconnector.
- The Herat area is served from the import line Mary (TKM) - Tourgundi (AFG) - Noor Jahad and from Iran.
- The border area of Nimroz province is served from Iran at a voltage level less than 110 kV.
- SEPS consists of four substations including Kandahar and Helmand. They are served by the Kajaki HPP and thermal generation in Kandahar.

A detailed list of equipment installed in the Afghan power system is given in **Annex 5.3**.

5.3.4 Transmission lines

Currently, the voltage levels 220 kV, 110 kV and 132 kV are used in the transmission system of Afghanistan. The following designs are used for transmission lines:

- double circuit line with double conductor bundle
- double circuit line with single conductor
- single circuit line with single conductor.

The following main conductor types used were identified

Type	Voltage level [kV]
ACSR 120	110
ACSR 185	110
ACSR 300	220
ACSR 490	220

Table 5.3.4-1: Conductor types mainly used in the Afghan power system

Single conductor configuration is applied on all transmission lines. The line Naibabad to Pul-E-Chomri, however, is equipped with double bundle conductors.

The tie-in distances for the following have not yet been identified, so they were assumed to be 1 km. They are highlighted in **Annex 5.3-1**:

- tie-in of Khulm to TL Naibabad - Pul-e-Chomri
- tie-in of Aybak to TL Naibabad - Pul-e-Chomri
- tie-in of Khenjan to TL Pul-e-Chomri - Charikar
- tie-in of Baghlan to TL Pul-e-Chomri - Sherkhanbandar
- tie-in of Kunduz#2 to TL Pul-e-Chomri - Sherkhanbandar
- tie-in of Sarobi (Town) to TL Naghlu - Sarobi
- tie-in of Rubat Sangi to TL Tourgundi - Noor Jahad
- tie-in of Ghorian to TL Islam Qala - Mir Dawood.

The distance from Naghlu to the tie-in point of Sarobi (Town) was assumed to be half the distance of the Naghlu - Sarobi TL of 6 km). No lengths could be found for the transmission lines in the Iran import system, principally the line from Islam Qala to Mir Dawood.

5.3.5 Substations

Annex 5.3-3 gives an overview of the existing substations.

Generally detailed information on substation busbar configuration and compensation or transformer equipment is very difficult to obtain. Some information is missing.

Currently there are 52 substations and these relate to the different power systems as follows:

Power system segment	Related provinces	Number of substations
NEPS Kabul	Kabul, Laghman, Logar Nangarhar, Paktia	13
NEPS TKM	Faryab, Jowzjan, Sar-e Pol	13
NEPS UZB & NEPS TAJ	Baghlan, Balkh, Kunduz, Parwan, Samangan, Takhar	15
Herat TKM	Herat	4
SEPS	Helmand, Kandahar	4
Herat Iran	Herat	4
Total		**53**

* Import substations (outgoing) are counted to the fed power system segment

Table 5.3.5-1: Number of existing* substations, June 2012

SS no.	SS name as used in the report	Province	Power system	Rated U [kV]
1	Chimtala	Kabul	NEPS Kabul	220
2	Kabul NW	Kabul	NEPS Kabul	110
3	Kabul N	Kabul	NEPS Kabul	110
4	Kabul E	Kabul	NEPS Kabul	110
5	Kabul Town	Kabul	NEPS Kabul	110
6	Botkhak	Kabul	NEPS Kabul	110
7	Pul-e-Charkhi	Kabul	NEPS Kabul	110
8	Sarobi (Town)	Kabul	NEPS Kabul	110
9	Mehtarlam	Laghman	NEPS Kabul	110
10	Jalalabad	Nangarhar	NEPS Kabul	110
11	Dasht-E-Barchi	Kabul	NEPS Kabul	220
12	Pul-E-Alam	Logar	NEPS Kabul	220
13	Gardez	Paktia	NEPS Kabul	220
14	Pul-e-Chomri	Baghlan	NEPS UZB & NEPS TAJ	220
15	Naibabad	Balkh	NEPS UZB & NEPS TAJ	220
16	Mazar-e-Sharif	Balkh	NEPS UZB & NEPS TAJ	220
17	Sheberghan	Jowzjan	NEPS TKM	110
18	Kwahja Doku	Jowzjan	NEPS TKM	110
19	Andkhoy	Faryab	NEPS TKM	110
20	Sherin Tagab	Faryab	NEPS TKM	110
21	Jumbazar	Faryab	NEPS TKM	110
22	Maimana	Faryab	NEPS TKM	110
23	Sar-e Pol	Sar-e Pol	NEPS TKM	110
24	Kunduz	Kunduz	NEPS UZB & NEPS TAJ	110
25	Kunduz#2	Kunduz	NEPS UZB & NEPS TAJ	220
26	Taluqan	Takhar	NEPS UZB & NEPS TAJ	220
27	Baghlan	Baghlan	NEPS UZB & NEPS TAJ	220
28	Imam Sahib	Kunduz	NEPS UZB & NEPS TAJ	110
29	Khenjan	Baghlan	NEPS UZB & NEPS TAJ	220

SS no.	SS name as used in the report	Province	Power system	Rated U [kV]
30	Charikar	Parwan	NEPS UZB & NEPS TAJ	220
31	Aybak	Samangan	NEPS UZB & NEPS TAJ	220
32	Khulm	Balkh	NEPS UZB & NEPS TAJ	220
33	Rubat Sangi	Herat	Herat TKM	110
34	Noor Jahad	Herat	Herat TKM	110
35	Sangin North	Helmand	SEPS	110
36	Lashkargah	Helmand	SEPS	110
37	Kandahar	Kandahar	SEPS	110
38	Musa Qala	Helmand	SEPS	110
39	Mir Dawod	Herat	Herat Iran	132
40	Ghorian	Herat	Herat Iran	132
Import substations (outgoing)				
1	Zohak	Iran	-	20
2	Turbat-i-Jam	Iran	-	20
3	Taibat	Iran	Herat Iran	132
4	Mary	Turkmenistan	Herat TKM	110
5	Zernow	Turkmenistan	NEPS UZB & NEPS TAJ	110
6	Surkhan	Uzbekistan	NEPS TKM	220
7	Amu	Uzbekistan	NEPS TKM	110
8	Geran	Tajikistan	NEPS TKM	110
9	Sangtuda	Tajikistan	NEPS TKM	220
10	Zaranji	Tajikistan	NEPS TKM	110
Import substations (incoming)				
1	Islam Qala	Herat	Herat Iran	132/20
3	Tourgundi	Herat	Herat TKM	110
4	Aqeena	Faryab	NEPS TKM	110
6	Hayratan	Balkh	NEPS UZB & NEPS TAJ	220
8	Shirkhanbandar	Kunduz	NEPS UZB & NEPS TAJ	220/110

Table 5.3.5-2: Substations in the Afghan power system, June 2012

The medium voltage levels at all substations were set to either 20 kV or 11 kV, with the 15 kV level eliminated.

For network development planning, it will likely be worthwhile to investigate the key sections of the external power grids of the connected countries.

5.3.6 Assets under construction

The inception report listed several assets under construction. It was decided to consider all of these as belonging to the data baseline. The following substations are therefore added to the existing ones and will be considered in the network planning.

SS name	Province
Dasht-E-Barchi	Kabul
Pul-E-Alam	Logar
Gardez	Paktia
Kunduz#2	Kunduz
Taluqan	Takhar
Baghlan	Baghlan
Imam Sahib	Kunduz
Khenjan	Baghlan
Charikar	Parwan
Aybak	Samangan
Khulm	Balkh

Table 5.3.6-1: Substations under construction considered for first development stage

As it was not possible to obtain detailed data on transformer types, i.e. short-circuit impedance or losses, the Consultant will base network calculations on transformer types derived from earlier projects specifically in Central Asia and in other countries.

Type [Label]	S_r MVA	$U_{r,p}$ kV	$U_{r,s}$ kV	r* [p.u]	x_{d*} [p.u]
220/110_160	160	220	110	0.001	0.069
220/20_40	40	220	20	0.008	0.275
220/20_25	25	220	20	0.008	0.275
220/20_16	16	220	20	0.008	0.275
220/110_200	200	220	110	0.001	0.055
220/110_63	63	220	110	0.003	0.159
220/110_50	50	220	110	0.003	0.159
220/110_40	40	220	110	0.003	0.159
220/110_25	25	220	110	0.003	0.159
Import_BT_220	300	220	11	0.000	0.000
Import_BT_110	300	110	11	0.000	0.000
132/6_50	50	132	6	0.005	0.340
110/20_15	15	110	20	0.014	0.400
110/6_2,5	3	110	6	0.014	0.400
110/15_25	25	110	15	0.014	0.400
110/15_20	20	110	15	0.014	0.400
110/20_25	25	110	20	0.014	0.400
110/10_6,3	6	110	10	0.014	0.400
110/20_16	16	110	20	0.014	0.400
110/6_10	10	110	6	0.014	0.400
110/20_10	10	110	20	0.014	0.400
110/20_40	40	110	20	0.005	0.340
110/20_4	4	110	20	0.005	0.340
110/10_40	40	110	10	0.005	0.340
110/10_26	26	110	10	0.005	0.340
110/10,5_21	21	110	11	0.005	0.340
110/10_16	16	110	10	0.005	0.340
110/6_16	16	110	6	0.005	0.340

Table 5.3.6-2: Transformer data used for modeling

*where: $r\,[p.u.] = \frac{R_{act}}{\frac{U_{r,p}{}^2}{S_{BASE}}}, S_{BASE} = 100MVA$

5.3.7 Generation assets

Annex 5.3-4 gives details of the generators used in the network model.

The respective generators for the transmission system are listed in Table 5.3.7-1. The total generating capacity is 340 MW, which is mainly concentrated in the Kabul power system.

Name	Type	Power system	Capacity [MW]
Tarakhil	Diesel Gensets	NEPS-Kabul	105
Darunta	Hydro	NEPS-Kabul	8,9
Mahipar	Hydro	NEPS-Kabul	55
Naghlu	Hydro	NEPS-Kabul	75
Sarobi	Hydro	NEPS-Kabul	22
Kabul GT	Thermal	NEPS-Kabul	40
Kajaki 1,3	Hydro	SEPS	33
Total			338,9

Table 5.3.7-1: On-grid generation assets, June 2012

6. Projects as Candidates for Generation and Transmission Expansions

The following chapters describe candidates for additional generation capacity, additional import capacity and major transmission project. These candidates are included as options in the optimization model. The optimization process will identify the optimal parameters (e.g. start of production) and the best combination of the defined candidates.

Scenario parameters for uncertainties are defined on the basis of an analysis of the main influencing factors on the behavior of the overall system.

The results of the optimization process are given in Chapter 10. They show that sources of power, local generation as well as import from neighboring power systems will be required to cover the expected demand growth in Afghanistan. Furthermore, the optimization exercise considered several cases with different load scenarios and different assumptions for the discount rates. The following sections present the available generation options as well as the selected option according to the results of the optimization process.

6.1 Options for Power Generation

The list of generation candidates includes hydropower options as well as the thermal generation option using local gas and coal deposits.

Expansion of local generation will lead to an independent power supply in Afghanistan but focusing on local generation for covering the expected demand will need great efforts to build new power plant facilities.

The estimated construction period for new hydropower plants of about 8 years and the uncertainties in development of the coal deposits

6.1.1 Hydro power plants

From the various available sources and information gathered during the meetings with the Afghan representatives, the following list of the most worthwhile hydropower projects was drawn up. Unfortunately it was not possible to obtain the current studies/feasibility studies on individual projects from the relevant Afghan organizations, so the following is based on publicly available information and the best knowledge of the Consultant. The table in **Annex 6.1.1-1** shows the various items of data obtained for the hydropower projects. The table below is an extract of the key characteristics of the projects used in the following for preparation of the power sector master plan.
Earliest possible commissioning date as given in Table 6.1.1-1 is based on the assessment of the available documents. This earliest commissioning date is used within the optimization process to elaborate the optimized commissioning date of the power plant.

No	Project	River	Province	Capacity [MW]	Comm. date	Annual energy [GWh]	Est. cost [$m]
1	Baghdara	Panshir	Kapisa/ Parvan	210	2021	968	600
2	Surobi 2	Kabul	Lagman	180	2021	891	700
3	Kunar A (Shal)	Kunar	Kunar	789	2022	4772	2000
4	Kajaki Addition	Helmand	Helmand	100	2021	493	300
5	Kukcha	Kukcha	Badakhshan	445	2022	2238	1400
6	Gulbahar	Panshir	Panshir/ Baghlan	120	2021	594	500
7	Capar	Panshir	Panshir	116	2021	574	450
8	Kama	Kunar	Nangarhar	45	2021	223	180
9	Kunar B (Sagai)	Kunar	Kunar	300	2021	1485	600
10	Kajaki Extension	Helmand	Helmand	18.5	2015	91	90
11	Olambagh	Helmand	Uruzgan	90	2021	444	400
12	Kilagai		Baghlan	60	2021	297	250
13	Salma	Hari Rud	Herat	40	2020	197	200
14	Upper Amu	Amu Daria		1000	2023	4955	2500
15	Dashtijum	Pyanj		4000	2023	19819	8000

Table 6.1.1-1: List of hydropower plant options

For an optimistic scenario the assumption on the earliest commissioning date for the Surobi 2 HPP (180 MW) and the Kajaki Addition HPP (100 MW) were adjusted according to the discussion during the draft final meeting held in Stuttgart on 11. and 12. February 2013 to the following:
Earliest commissioning of Surobi 2 HPP (180 MW) will be year 2018
Earliest commissioning of Kajaki Addition HPP (100 MW) will be year 2017.

6.1.1.1 Description of hydropower options

Baghdara Hydropower Plant

Baghdara hydroelectric project is located on the Panjshir River, east of Baghdara village northeast of Kabul. The source of this river is in the vicinity of Anjuman Pass at about 4500 masl, in the north-eastern part of the country. The river first flows southwest before joining the Ghorband River and turning east, where it enters a large, cultivated flood plain. Then it enters a long gorge, turns south and finally discharges into the Naghlu reservoir.

The project’s potential reservoir and its associated structures (dam, headrace tunnel, powerhouse, etc.) are located along the gorge of the Panjshir River. The installed capacity is 210 MW and the average annual energy production is 967 GWh.

Surobi 2 Hydropower Plant

Surobi 2 hydroelectric project is located downstream of the Surobi 1 HPP, so uses its discharge.

This hydro power plant, with an installed capacity of 180 MW and average annual energy production of 890 GWh, is at an elevation of 970 masl and discharges through an 18.9 km tunnel to a tailrace at 770 masl.

Baghdara Hydropower Plant is also located upstream of the Surobi 2 project and has a reservoir of 800m m^3 capacity, so the Baghdara reservoir will influence operation of Surobi 2 HPP. The Consultant therefore recommends conducting a feasibility study, including operation of Baghdara reservoir, environmental impact studies and socio-economic studies.

Kunar A (Shal) Hydropower Plant

The Kunar A hydropower project is located on the Kunar River about 7 km of Asmar and has a regulation reservoir with an active storage capacity of 1.0m m^3. The dam is of earthfill construction and the length of the diversion tunnel is 1050 m.

With regard to capacity, we found some inconsistencies, namely: the Power Sector Master Plan (Norconsult-Norplan, 2004) states that the installed capacity is 368 MW (4 x 91.5 MW), which is contradicted by the National Energy Supply Program (NESP, 2012) stating an installed capacity of 789 MW.

For the main investment opportunities in Afghanistan (Afghanistan Investment Support Agency, 2009), it was stated that the hydropower potential of the Kunar River basin is 300 MW (Kunar B - Sagai) in the first stage and 900 MW (Kunar A - Shal) in the second stage. The total cost of the project is about US$1.8 billion. If this project finds financing, it will take an estimated 5 years to complete and all provinces of Afghanistan will benefit, not just Kunar. The feasibility study for this project was already completed in 2008.

Kajaki Addition 2 Hydropower Plant

The Kajaki hydropower project has a regulation reservoir with a storage capacity of 1.7m m^3. The dam is of the rockfill type and was constructed in 1952 for irrigation purposes. The dam height is 98 m. The project aims to increase the active storage capacity from 1.7m m^3 to 2.7m m^3. The project also proposes installation of a second power house to generate 100 MW. The annual average energy production is 492 GWh.

The dam is over 60 years old, so reservoir capacity must have been reduced due to sedimentation, so it is advisable to know its current capacity.

The Consultant also recommends undertaking a feasibility study, with investigations into raising the reservoir height; reservoir sedimentation; evaluation of active storage capacity; evaluation of a second power house; evaluation of multipurpose water use for irrigation, water supply and power generation; simulation of electrical energy generation; and the reservoir operating regime.

Kukcha (Takhar) Hydropower Plant

Along the Kukcha River in the north-east provinces of Badakhshan and Takhar, a potential of over 1500 MW of hydro power is expected but studies and further information are available only for small power plants. The power plant mentioned in the National Energy Supply Program (NEPS) with an installed capacity of 445 MW could not be verified against other sources. However it is assumed that the potential along Kukcha River could be developed to this level and preparation of a feasibility study for the 445 MW power plant is required. Regarding annual average energy production, 2238 GWh could be expected for the 445 MW power plant along the Kukcha.

Gulbahar Hydropower plant

Gulbahar HPP is located on the Panjshir River approximately 1.5 km upstream of Gulbahar city. It has a regulation reservoir with a capacity of 0.760m m^3 with multipurpose water use for irrigation and electricity generation.

The dam is of the rockfill type with a height of 200 m. the installed capacity of the power house is 120 MW with 4 Francis turbines. The average annual energy production is 593 GWh.

Multipurpose reservoir operation should be investigated in the feasibility study. The feasibility for peaking purposes should also be investigated.

Capar Hydropower Plant

Capar HPP is located on the Panjshir River, downstream of Baghdara HPP, utilizing the head between the tail waters of Baghdara and the head pond of Naghlu Reservoir. The installed capacity is 116 MW and the average annual energy production is 574 GWh.

As the Baghdara Reservoir is used for seasonal regulation, it influences the Capar hydropower project, so the feasibility study should consider its operation.

Kama Hydropower plant

The Kama hydroelectric plant is located on the Kunar River immediately upstream of its confluence with Kabul River. The Kama dam has a regulation reservoir for multipurpose water use for irrigation and power generation.

According to the Power Sector Master Plan (Norconsult-Norplan 2004), the water is taken from the Kunar River and transported through about 16 km of canals and tunnels until a point where water for irrigation and water for hydropower are split into two separate systems. The water for irrigation continues further along a canal system, while water for hydropower is led through a headrace tunnel to a head pond and then via a penstock to the powerhouse. A tailrace canal releases the discharge into the Kabul River.

The installed capacity is 45 MW, with three units; the average annual energy production is 222 GWh. Multipurpose reservoir operation should be investigated in the feasibility study.

Kunar B (Sagali) Hydropower Plant
The Kunar B hydropower project is located on the Kunar River about 22 km upstream of Asmar. It has a regulation reservoir with a storage capacity of 7.0m m^3 and a 105 m high earth fill dam.

With regard to capacity, we found some inconsistencies, namely: the Power Sector Master Plan (Norconsult-Norplan, 2004) states that the installed capacity is 165 MW (3 x 55 MW), which is contradicted by National Energy Supply Program (NESP 2012) stating an installed capacity of 300 MW.

For the main investment opportunities in Afghanistan (Afghanistan Investment Support Agency 2009), it was stated that the hydropower potential of the Kunar River basin is 300 MW (Kunar B - Sagai) in the first stage and 900 MW (Kunar A - Shal) in the second stage. The total cost of the project is about US$1.8 billion. If this project finds financing, it will take an estimated 5 years to complete and all provinces of Afghanistan will benefit, not just Kunar. The feasibility study for this project was already completed in 2008.

Kajaki Extension Hydropower Plant
The Kajaki dam and hydropower plant is located on the Helmand River, 95 km northwest of Kandahar city. The dam was completed in 1952 and was built for irrigation purposes.

The first stage of the hydropower component was completed in 1975, with installation of 2×16.5 MW with provision made for a third unit of 18.5 MW at a later stage. Its installation will have a negligible environmental impact.

The turbines were installed 30 years ago. In the feasibility study for installation of the third unit, complete rehabilitation of the two existing units should be investigated.

The new installed capacity is 45 MW and the average annual energy production is 91 GWh.

Olambagh Hydropower Plant
The Olambagh hydropower project is located on the Helman River in Kandahar Province near Olambagh village, which is about 75 km upstream of Kajaki. The project location is upstream of the Kajaki hydropower project.

The project has a reservoir with an active storage capacity of 1.194m m^3. It has a rockfill dam with a height of 38 m. This reservoir also works as a sand trap, extending the life of the Kajaki reservoir, which is very favorable to the Kajaki project.

The installed capacity is 3 x 30 MW and the average annual energy production is 443 GWh.

The Consultant recommends conducting a feasibility study including an investigation of reservoir operation and the influence of this reservoir on the Kajaki project

Kilagai Hydropower Project
Kilagai HPP is an irrigation and power supply project. Its cost is about US$350m and it benefits people in Baghlan province. The feasibility study has already been completed and submitted to the Ministry of Water and Energy (main Investment Opportunities in Afghanistan, 2009).

The project will have the following impacts: reliable supply of water for irrigating 68,000 ha land; provision of water to newly irrigate 25,365 ha land; hydropower generation of 60 MW to benefit producers and consumers; provision of land for landless farmers; contribution to security of the national food (production of more crops, fishery and industry); upgrading the environment and creation of forests; jobs opportunity and attraction of tourism industry.

Sedimentation in headrace canals and erosion of turbine parts are serious operational problems for the existing Pul-e-Chomri I and Pul-e-Chomri II HPPs. A reservoir at Kilagai will trap the sediments and thereby solve these problems at the two existing downstream power plants (Power Sector Master Plan, 2004).

Salma Hydropower Plant
The Salma project site is located on the Hari Rod River in Herat province. The Salma project was planned to provide irrigation benefits in the Hari Rod basin.

Salma dam was originally constructed in 1976 on the Hari River, but was damaged early on during the civil war in Afghanistan. Reconstruction of the dam was first initiated by an Indian company, WAPCOS Ltd., in 1988, but the project was left incomplete for a lengthy period due to the ongoing instability caused by the civil war. In 2006, India committed to funding completion of the Salma Dam at an estimated cost of $200. The dam is currently under construction and is planned for completion in 2012.

Once completed, the hydropower plant would generate 40 MW in addition to providing irrigation for 75,000 ha of farmland. Average annual energy generation is 197 GWh.

Upper Amu Hydropower Plant
The Upper Amu hydropower project is located on the transboundary Pyanj River. The project has the following technical data: mean inflow 1720 m^3/s, gross head 345 m, and active storage capacity 15,200m m^3. The installed capacity is 1000 MW and annual energy production is 4954 GWh (Power Sector Master Plan, Norconsult 2004 and The Prospect of Hydropower Development in Tajikistan, Ministry of Energy and Industry, Republic of Tajikistan, 2007).

According to the main investment opportunities in Afghanistan (Afghanistan Investment Support Agency, 2009), the Upper Amu Irrigation and Hydropower Project will generate an estimated 1000 MW of electricity for the northern provinces of Afghanistan and would irrigate large areas of desert and land. The estimated cost of the project is about US$3 billion.

Dashtijum Hydropower Plant
The Dashtijum hydropower project is located on the Pyanj River at a distance of around 280 km southeast of the Tajik capital, Dushanbi. The Pyanj River forms the border between the Republic of Tajikistan and the Islamic Republic of Afghanistan.

According to information from Barki Tojik (Tajikistan), the Government of Afghanistan prepared a feasibility study, which is available to neither Barki Tojik nor the Consultant. Besides hydropower planning, irrigation planning needs to be completed for a 1.5m ha area. Planning of irrigation has to be done prior to hydropower planning, so additionally 5 years have to be considered for the development

The project layout envisages a large rockfill dam with short connecting tunnels through the right rock flanks of the mountains to the surface powerhouse. The project is planned with 5 units, each rated at 800 MW. The specific purpose of the project is irrigation, which has a higher priority than electricity generation. The project is trans-national in character.

The nearest grid connection to the HPP is at Khatlon at 220 kV. Evacuation of the electricity from Dashtijum requires a voltage level of 500 kV and at least three transmission lines. Line routing – west to Baipaza, north to Tabildara and/or south to Geran – must be defined before the cost can be estimated. The line routing will depend on the share of export energy and energy for domestic use.

The installed capacity is 4000 MW (5 x 800) and the average annual energy is 19,820 GWh.

6.1.1.2 Conclusion on hydropower projects

The optimization process considered the candidates as discussed above with the corresponding capital costs for construction of the hydropower plants.

Unfortunately it was not possible to obtain the current studies/feasibility studies on individual projects from the relevant Afghan organizations, so the work has to be based on publicly available information and the best knowledge of the Consultant.
Preparation or update of feasibility studies for the different power generation projects have to be done to provide other reliable documents for further assessment of the power generation options for potential update of the Power Sector Master Plan.

The following Table 6.1.1-2 gives an overview of the HPP options and the required capital expenditure (CAPEX) and already takes into consideration the optimization results for the base load case and a discount rate of 12% as a proposal for usage of the hydro resources within the timeline. Due to the high discount rate given by ADB as standard, usage of the huge hydro resources is shifted to a later implementation stage. The table contains all the hydropower generation options, the selected option for the base load scenario as well as the option only for the high load scenario, and the options that were not selected during optimization. Calculation of the total CAPEX considered only the hydropower plants used in the base case scenario.

Hydropower plants		Capital costs [m$]				
		Subtotal by project	Stage A	Stage B	Stage C	Stage D
G_01	Salma HPP	200.0	200.0			
G_02	Kajaki Expansion HPP	90.0	90.0			
G_03	Baghdara HPP	600.0				600.0
G_04	*Sarobi HPP**	*700.0*				*700.0*
G_05	Kunar A HPP	2000.0				2000.0
G_06	Kajaki Addition HPP	300.0				300.0
G_07	*Kukcha HPP**	*1400.0*				*1400.0*
G_08	*Gulbahar HPP**	*500.0*				*500.0*
G_09	*Kama HPP***					*180.0*
G_10	Kunar B HPP	600.0			600	
G_11	*Kilagai HPP***					*250.0*
G_12	Olambagh HPP	400.0				400.0
	Total	4190.0	290.0	0.0	600	3300.0

* Power plant selected only in high load scenario
** Power plant not selected in optimization process

Table 6.1.1-2: Summary of capital costs for hydropower plant projects optimized scenario

Measures to be taken within the transmission network for integration of the new power plants are discussed in detail in section 8.2. A summary of the required CAPEX is given in Table 6.1.1-3 below. Calculation of the total CAPEX for network connection considered only the preferred options according to the base case scenario.

Network connection of hydropower plants		Capital costs [m$]				
		Subtotal by project	Stage A	Stage B	Stage C	Stage D
GN_01	Salma HPP	36.6	36.6			
GN_02	Kajaki Expansion HPP	1.1	1.1			
GN_03	Baghdara HPP	14.8				14.8
GN_04	*Sarobi HPP**	*13.2*				*13.2*
GN_05	Kunar A HPP	86.8				86.8
GN_06	Kajaki Addition HPP	14.8				14.8
GN_07	*Kukcha HPP**	*70.3*				*70.3*
GN_08	*Gulbahar HPP**	*11.4*				*11.4*
GN_09	*Kama HPP***					
GN_10	Kunar B HPP	33.0			33.0	
GN_11	*Kilagai HPP***					
GN_12	Olambagh HPP	10.3				10.3
	Total	197.3	37.6	0.0	33.0	126.7

* Power plant selected only in high load scenario
** Power plant not selected in optimization process

Table 6.1.1-3: Summary of capital costs for network connection for hydropower plant projects optimized scenario

Selected commissioning date of the hydro power plants according optimized expansion plan are as given in the following Table 6.1.1-4:

First year of operation	Hydro Power Plant	Installed capacity
finalizing expected soon	Salma	40 MW
finalizing expected soon	Kajaki Expansion	18.5 MW
2024	Kunar B	300 MW
2026	Kunar A	789 MW
2028	Kajaki Addition	100 MW
2029	Olambagh	90 MW
2032	Baghdara	210 MW

Table 6.1.1-4: Expected first year of operation for the hydro power plants selected according to the optimized scenario

For the optimistic assumption of early commissioning of Surobi 2 HPP and Kajaki Addition HPP the resulting optimization procedure gives a different ranking of the power plants and therefore different Schedule for the investment in the power plants and the required network integration of the power plants as shown in the following Table 6.1.1-5 and Table 6.1.1-6.

Hydro Power plants		Capital costs [m$]				
		Subtotal by project	Stage A	Stage B	Stage C	Stage D
G_01	Salma HPP	200.0	200.0			
G_02	Kajaki Expansion HPP	90.0	90.0			
G_03	*Baghdara HPP*	*600.0*				*600.0*
G_04	Sarobi 2 HPP	700.0		700.0		
G_05	Kunar A HPP	2000.0				2000.0
G_06	Kajaki Addition HPP	300.0		300.0		
G_07	*Kukcha HPP**	*1400.0*				*1400.0*
G_08	*Gulbahar HPP**	*500.0*				*500.0*
G_09	Kama HPP	180.0				180.0
G_10	Kunar B HPP	600.0				600.0
G_11	*Kilagai HPP***					*250.0*
G_12	Olambagh HPP	400.0				400.0
	Total	4470.0	290.0	1000.0	0.0	3180.0

Table 6.1.1-5: Summary of capital costs for hydropower plant projects, optimistic scenario

Network connection of Hydro Power plants		Capital costs [m$]				
		Subtotal by project	Stage A	Stage B	Stage C	Stage D
GN_01	Salma HPP	36.6	36.6			
GN_02	Kajaki Expansion HPP	1.1	1.1			
GN_03	*Baghdara HPP*	*14.8*				*14.8*
GN_04	Sarobi 2 HPP	13.2		13.2		
GN_05	Kunar A HPP	86.8				86.8
GN_06	Kajaki Addition HPP	14.8		14.8		
GN_07	*Kukcha HPP**	*70.3*				*70.3*
GN_08	*Gulbahar HPP**	*11.4*				*11.4*
GN_09	Kama HPP	10.0				10.0
GN_10	Kunar B HPP	33.0				33.0
GN_11	*Kilagai HPP***					
GN_12	Olambagh HPP	10.3	0.0	0.0	0.0	10.3
	Total	205.8	37.6	28.0	0.0	140.1

Table 6.1.1-6: Summary of capital costs for network connection for hydropower plant projects, optimistic scenario

The expected commissioning years of the hydro power plants for the optimistic scenario are as given in Table 6.1.1-7 below.

First year of operation	Hydro Power Plant	Installed capacity
finalizing expected soon	Salma	40 MW
finalizing expected soon	Kajaki Expansion	18.5 MW
2020	Kajaki Addition	100 MW
2020	Surobi 2	180 MW
2027	Kunar A	789 MW
2029	Olambagh	90 MW
2031	Kunar B	300 MW
2032	Kama	45 MW

Table 6.1.1-7: Expected first year of operation for the hydro power plants selected according to the optimistic scenario

6.1.2 Thermal power plants

Afghanistan has to overcome two major obstacles to build up its power generating capacity: first feasibility of projects in general and second the affordability of the produced electricity.

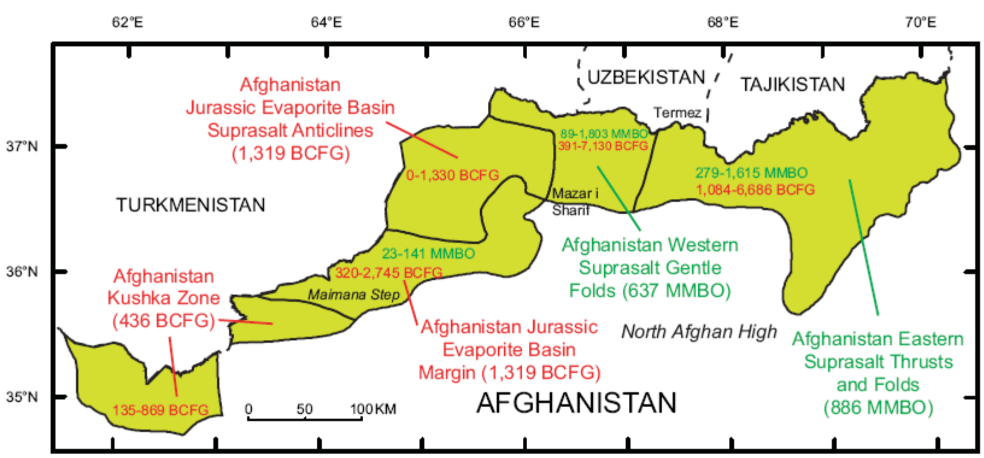
The prime concern for installing power generation capacity in Afghanistan is project feasibility. Because the security situation is deteriorating year by year, it would be difficult or even impossible to implement anything other than simple construction projects.

To obtain affordable electricity, Afghanistan has to exploit its domestic energy resources of which there are three:

- natural gas
- coal
- oil.

6.1.2.1 Natural gas resources and reserves

Natural gas is found in the north of Afghanistan. An assessment can be based on geological data and historical prospecting for petroleum sources that was done by the USGS. An estimate for unrecovered petroleum volumes is given in Figure 6.1.2-1.



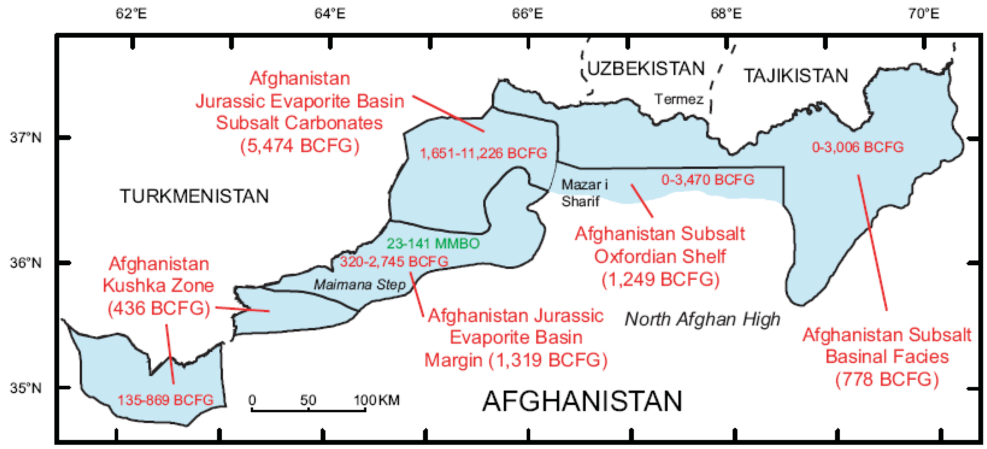


Figure 6.1.2-1: Map showing locations of geological assessment units and estimated undiscovered petroleum resources: The means of the estimates are stated next to the assessment unit name and the ranges are given within the assessment unit boundaries. BCFG is billion cubic feet of natural gas and MMBO is million barrels of crude oil. (USGS)

The petroleum resources potential is located in two geological basins – the Amu Darya basin to the west and the Afghan Tajik basin to the east.

A distinction has to be made between a resource, which is the amount of gas or oil actually in a geological formation, and a reserve, which is that part of the potential that can be recovered under favorable economic conditions.

The resources have been assessed by the US Geological Survey and the Afghan Ministry of Mines and Industry and estimated as 444bn m^3 of undiscovered technically recoverable natural gas in addition to the identified reserves.

All identified reserves and productive wells are located in the vicinity of Sheberghan. The reserve estimates for the producing and discovered fields that are of economic importance are given in Table 6.1.2-1.

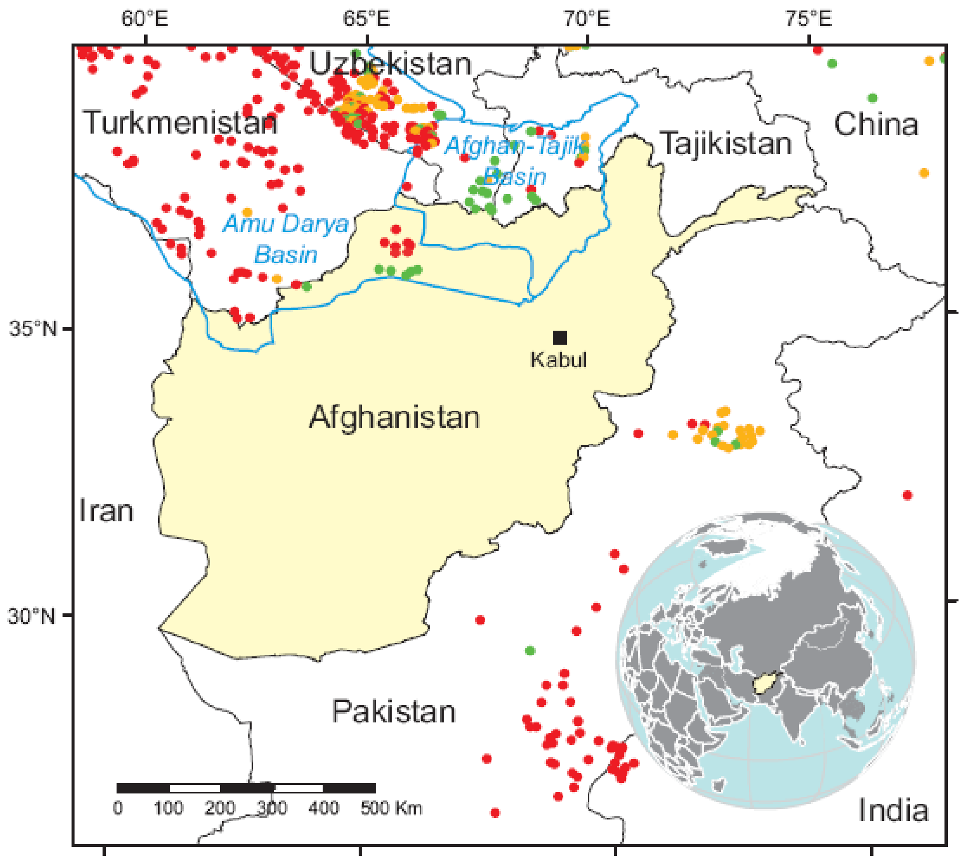


Figure 6.1.2-2: Map of Afghanistan showing the locations of Amu Darya and Afghan-Tajik basins, and approximate locations of fields and discoveries that contain primarily crude oil (green) and natural gas (red). Field discovery locations from IHS Energy (2005)

Reserve estimates (Gustavson, 2005)	Remaining gas reserves BCM	Remaining gas reserves BCF	Thermal equivalent 10 kWh/m³ GWh	Hypothetical range for 100 MW power plant 35%eff., 8500 h/year Years
Bashikurd	6.37	225	63,700	26
Yatimtaq	7.36	260	73,600	30
Jar Quduk (Gerqudug)	9.77	345	97,700	40
Jangalikolon	13.38	472	133,800	55
Kohja Gogerdaq	16.77	592	167,700	69
Juma	21.82	770	218,200	90
Total	**75.47**	**2,665**	**754,700**	**311**

Table 6.1.2-1: Reserve estimates of discovered and producing gas fields

The Sheberghan gas field provides the opportunity to supply fuel for a power plant. Currently, the gas wells of the Sheberghan gas fields are producing but need rehabilitation. The wells were drilled by Russian exploration teams and were abandoned in the early 1990s. At present, 450,000 m^3/d (continuously 187 MWth) natural gas is produced at four fields from 35 wells around Sheberghan. This gas is distributed to domestic consumers and the fertilizer plant at Mazar-e-Sharif. The raw gas contains H_2S at various concentrations, depending on the originating well. The H_2S concentration at some wellheads is 0% and more than 1.4% at others. A huge proportion of the gas is distributed as raw, unsweetened, gas. H_2S causes corrosion of the gas facilities and is very poisonous.

At present, the gas is distributed for 3.9 $/MWh. According to AEAI （AEAI，2010）the gas price after rehabilitation of the wells would be 10.4 $/MWh, allowing a return on investment for the gas producer of 20%. A typical wellhead price for natural gas (USA) is 14.1 $/MWh. An overview of the prices is given in Table 6.1.2-2.

Item	Price, $/MWh lower heating Value
Gas price, existing well	3.9
Gas price, refurbished well	10.4
Gas price, wellhead USA	14.1

Table 6.1.2-2: Overview of gas prices, Sheberghan

6.1.2.2 Gas-fired power plants

To exploit the domestic energy source at Sheberghan, a 200 MWe gas-fired power plant has been proposed for connection to the NWPS grid. The following Table 6.1.2-3 shows the main features of the proposed power plant at Sheberghan.

Item	Unit	Value
Total capacity	MW_e	200
Generator rating	MW_e	25
CAPEX, CCPP	$/kW	1,700
CAPEX, reciprocating engine PP	$/kW	1,200
OPEX	$/MWh	9.5
Efficiency	%	38 - 45
Fuel consumption, eff. = 40%	MW	500
Fuel consumption	MWh/d	12,000
Fuel consumption	m^3/d	1,200,000

Table 6.1.2-3: Main features of the Sheberghan gas-fired power plant

It is not known by the Consultant which type of power plant is preferred for the Sheberghan power plant.

In the following Table 6.1.2-4, the main features of CCPP and reciprocating engine power plant technology are compared.

Reciprocating engine power plant	Combined cycle power plant
Well established technology	Very complex technology: - gas and steam turbine technology - water-steam cycle & heat recovery boiler - demineralization plant
Simple project management	Interdependent units
Small units possible	Might operate without gas sweetening plant, depending on manufacturer
Units are independent	
High grid stability	
Staged project development possible: power plant can "grow" from 5 MW to any capacity	

Table 6.1.2-4: Main features of reciprocating engine power plant versus combined cycle power plant

The fuel consumption of a 200 MWe power plant is about three times as much as the present gas production of the Sheberghan gas fields: 1,200,000 m^3/d power plant consumption versus 450,000 m^3/d production. There are two options for handling this situation, while avoiding abandonment of the existing consumers.

First, the gas-fired power plant is phased in by installing small units, ultimately at wells with naturally sweet gas, and increasing the size of the power plant in parallel with the development of the gas fields.

Second, the gas fields are developed to their full production capacity to supply gas for the power plant.

In either case, to achieve a capacity of 200 MWe, the gas fields have to be developed with new wells and the gas price will increase from 3.9 $/MWh at present to 10.4 $/MWh.

6.1.2.3 Summary for natural gas-fired power plants

- A 200 MWe gas-fired power plant cannot be installed at the present rate of gas production. New wells have to be drilled.
- There is enough gas, discovered and undiscovered, in northern Afghanistan to supply gas to a number of gas-fired power plants. The wells for extracting this gas have to be installed.
- A reciprocating engine power plant is simpler in technology and project management and can be installed in smaller units. As a start-up strategy, units of a reciprocating engine power plant can already be installed and produce electricity from today on. The power plant can be expanded in parallel with the development of the fields.
- There is potential for developing gas fields and produce electricity from gas for Herat as well. However, this potential and the feasibility of recovery of gas at an economic cost would have to be geologically verified.

6.1.2.4 Coal resources and reserves

Coal is a further domestic energy resource of Afghanistan with the potential to contribute as a fuel source for thermal power production. The coal reserves of Afghanistan are estimated to be 73 million tons（Malik，2011）. However the US Geological Survey states: “very little is known about the character of the Afghan coal resource and much of the existing data is not readily available to potential users” (2005).

Today coal is produced by artisanal mines and delivered by road to the consumer. It is used by kilns for brick production, a cement factory and domestic consumers. The coal production of Afghanistan is estimated to be 35,000 metric tons per year as per 2008. The pre-war coal production of Afghanistan peaked in 1987 at 167,000 metric tons per year (EIA, 2012).

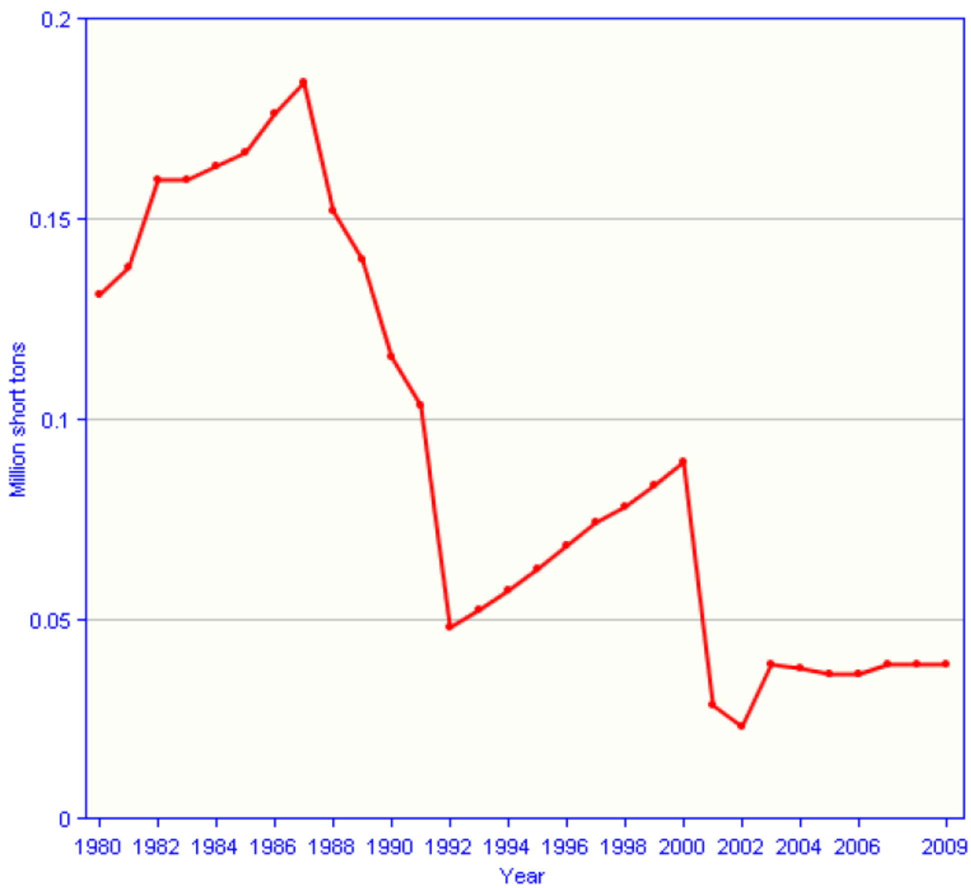


Figure 6.1.2-3: Coal production of Afghanistan (1 short ton = 0.9 metric ton)

The confirmed quantity and quality of coal resources remain relatively unknown but appear to be good.（Malik，2011）

The current price ranges from $65 to $90 per ton depending on transport costs. The actual price per ton is estimated to be around $20 to $25 (run of mine)（Malik，2011）.

6.1.2.5 Coal-fired power plants

Two power plants have been proposed by mining companies for the Aynak copper mine and the Hajigak iron ore mine.

Typical features of the power plants are given in Table 6.1.2-5.

Item	Unit	Value	Value
Power plant		Aynak	Haji Gag
Proposed capacity	MW	400	800
Capacity fed to Grid	MW	200	200
CAPEX	$/kW	1,700	1,700
OPEX	$/MWh	25	25
Net efficiency	%	32,5	32,5
Plant load factor	%	68	68
Operating hours	h/a	6,000	6,000
Total electricity production	GWh/a	2,400	4,800
Electricity Production fed to Grid	GWh/a	1,200	1,200
Total coal consumption	GWh/a	7,400	14,800
Coal consumption (36,000 kJ/kg)	mt/a	740,000	1,480,000

Table 6.1.2-5: Typical features of coal-fired power plants

The coal consumption of the power plants exceeds the peak production of pre-war Afghanistan by more than ten times. New mines have to be put into operation before the power plants can be integrated into the electricity production capacity. It is unknown if the necessary coal reserves exist in Afghanistan.

6.1.2.6 Conclusion for coal-fired power plants

- The consumption of coal-fired power plants would exceed the historic peak of Afghan domestic coal production by ten times. A mining plan with cost estimate for the coal is necessary to prove the feasibility of a power plant fired with domestic coal. An alternative to domestic coal would be imported coal, which would be imported by the mine operator by the same means of transport through which his mining product is exported. In this way, the electricity price of the coal-fired power plant would be linked to international coal prices. Even if coal is not used for power generation, a functioning domestic coal market could considerably relieve the energy shortage during winter.
- The major drawback of coal-fired power plants is the complexity of a steam plant, both during the building phase as well as during operation. It is very unlikely that an expensive and complex project like a 400–800 MW coal-fired power plant, as proposed for a mine at Bamyan, would be feasible under the prevailing conditions in Afghanistan. During construction, a workforce of about 2,000 skilled workers, many of them expatriates, would be needed. Huge amounts of building material and heavy special machinery have to be transported by truck.
- Grid-integration of generating capacity with a single unit capacity of 150 MWe is questionable.

- Even if a coal-fired power plant were feasible to serve the needs of a mine, it is suggested that, due to the huge single unit rating and a future mining plan, the capacity from a coal-fired power plant would have to be integrated into the master plan after 10 to 15 years.

6.1.2.7 Oil resources and reserves

Oil, which is found at the Shebergan field can either be refined to fuel or converted to power by an HFO-fired reciprocating engine. Burning crude oil in HFO diesel engines combines the simple project layout of diesel power plants with the availability of domestic energy resources.

6.1.2.8 Diesel-fired power plants

Small diesel power plants, comprising gensets ranging from 50 kW to a few MW, have the advantage of straightforward operation and easy maintenance but need diesel fuel, which must be imported to Afghanistan from Iran, the Central Asian Republics or Pakistan at international market prices. The price of diesel fuel is in the order of 60 AFN per liter (1 US$ = 43.025 AFN, Feb. 2011). Given a fuel efficiency of a genset of 35% and a heating value of 10 kWh/kg, the resulting electricity price is 40 $/MWh considering the costs for fuel only. Electricity at this price level would not be affordable for most people in Afghanistan. However diesel gensets are appropriate for low consumption consumers of high importance like hospitals and communication systems. Peak shaving and emergency power supply are further applications of expensive diesel generated power.

Features of a typical diesel-fired power plant are given in Table 6.1.2-6.

Item	Unit	Value
Rating	MW_e	0.05 - 500
Block capacity	MW_e	0.05 - 5
CAPEX, CCPP	$/kW	1,200
CAPEX, reciprocating engine PP	$/kW	1,200
OPEX	$/MWh	9.0
Efficiency	%	35 - 40

Table 6.1.2-6: Features of typical diesel-fired power plants

6.1.2.9 Summary of oil-fired power plants

Power generation by diesel-fired gensets is considered in the model according to the price of electricity generated by diesel.

6.1.2.10 Conclusion on thermal power projects

The identified options for thermal generation as described above are the Sheberghan gas-fired power plant and the coal-fired power plants at Ishpushta and Dara-i-Suf.

The Sheberghan TPP project is being developed by the support of USAID. For the coal fired power plants preparation of feasibility studies for the coal mining as well as for the thermal power plants have to be done to provide reliable documents for further assessment of the power generation options for potential update of the Power Sector Master Plan.

Sheberghan TPP will be the power plant with shortest lead time for construction. Two stages with 200 MW each were given as option for the optimization and both stages were selected at an early stage of the optimization process. Earliest date for commissioning of Sheberghan TPP was assessed for 2017.

The coal-fired power plants are related to the Aynak and Hajigak mining projects and commissioning of the coal-fired power plants is expected at the end of the planning horizon during development stage D.

The mining projects are very uncertain hence the earliest commissioning date for the coal fired power plant Ishpushta and for Dara-i-Suf is estimated for year 2027 and 2029.

The following table shows the expected CAPEX for thermal power plants for the optimized generation development.

Thermal power plants		Capital costs [m$]				
		Subtotal by TPP	Stage A	Stage B	Stage C	Stage D
G_21	Sheberghan TPP 2x200MW	680.0		340.0	340.0	
G_22	Ishpushta TPP 400MW	680.0				680.0
G_23	Dara-i-Suf TPP 800MW	1360.0				1360.0
	Total	2720.0	0.0	340.0	340.0	2040.0

Table 6.1.2-7: Summary of capital costs for thermal power plant projects optimized scenario

Network integration of the thermal power plants requires additional measures in the provinces as described in section 8.2.

Network connection of Thermal Power plants		Investment [m$]				
		Subtotal by project	Stage A	Stage B	Stage C	Stage D
GN_21	Sheberghan TPP	17.0		8.5	8.5	
GN_22	Ishpushta TPP	81.1				81.1
GN_23	Dara-i-Suf TPP	124.2				124.2
	Total	222.3	0.0	8.5	8.5	205.3

Table 6.1.2-8: Summary of capital costs for network connection for thermal power plant projects optimized scenario

Beside the coal fired power plants related to the mining project additional coal deposits could be developed and used for coal fired power plants. Using optimistic estimates for the exploitation of coal resources and the construction of a coal fired power plant were requested by Afghan government to support the goal of independent power production. Therefore an optimistic scenario was examined in addition to the optimized power generation plan and the earliest date of commissioning of a coal fired power plant was considered for year 2020.

The resulting list of CAPEX for the thermal power plants and network integration for the optimistic scenario is given in Table 6.1.2-9 and Table 6.1.2-10.

Thermal Power Plants		Capital costs [m$]				
		Subtotal by TPP	Stage A	Stage B	Stage C	Stage D
G_21	Sheberghan TPP 2x200MW	680.0		680.0		
G_22	Ishpushta TPP 400MW	680.0		680.0		
G_23	Dara-i-Suf TPP 800MW	1360.0				1360.0
	Total	2720.0	0.0	1360.0	0.0	1360.0

Table 6.1.2-9: Summary of capital costs for thermal power plant projects, optimistic scenario

Network connection of Thermal Power plants		Capital costs [m$]				
		Subtotal by project	Stage A	Stage B	Stage C	Stage D
GN_21	Sheberghan TPP	17.0		17		
GN_22	Ishpushta TPP	81.1		81.1		
GN_23	Dara-i-Suf TPP	124.2				124.2
	Total	222.3	0.0	98.2	0.0	124.2

Table 6.1.2-10: Summary of capital costs for network connection for thermal power plant projects, optimistic scenario

6.1.3 Renewable energy and power distribution

Renewable energies within the context of this study comprise energy generated by wind, the sun, geothermal energy and from biomass. Energy from hydro power plants is discussed separately.

The present use of renewable energy sources for electricity generation (apart from hydro power) is very limited within Afghanistan (see section 5.1.3). At the moment, there are basically no centralized power plants that utilize renewable energies like solar, wind, biomass or geothermal. The most promising of the available sources are solar and wind. After a brief discussion of biomass and geothermal energy, potential candidate projects for solar and wind are presented below.

6.1.3.1 Biomass

The production of electricity from biogas is a technologically demanding process which requires a certain feedstock. Usually this feedstock is organic waste or manure, which is supplied by larger farms. Since neither larger farms nor a selective waste collecting system with separate collection of organic waste is available today, biogas to electricity is not a realistic option to be applied on a large scale. Furthermore, the production of biomass (e.g. corn) as a co-substrate might be in competition with food production and the supply of basic energy for heating and cooking, which is especially important for rural populations with a low income. For this reason, biomass is not considered to be a contender for centralized electricity generation, so no candidate project is presented in this report.

6.1.3.2 Geothermal

Afghanistan possesses a certain potential for geothermal energy along the Hindu Kush **[MIN_006, p12]** but to exploit it certain conditions have to be met in terms of depth, temperature and chemistry to operate geothermal facilities economically. Since these conditions are largely unknown and need further time-intensive investigation, it is not expected that geothermal energy will contribute to centralized electricity generation over the medium term. In general, geothermal systems for electricity generation are not feasible for decentralized generation.

The exploration of geothermal for power generation needs extensive investigation of geological conditions as described above. There are no information given on such investigations and activities.
The activities for survey on geological conditions have to be started to allow an assessment on the use of these energy sources in later revisions of the Power Sector Master Plan. However it is not expected that geothermal power generation will have a significant part on the power generation within Afghanistan within the next 20 years.

6.1.3.3 Solar

Besides wind, electricity generation using solar systems is the most promising renewable energy source in Afghanistan. The description of solar energy systems in the following section will concentrate on photovoltaic systems. The use of solar thermal power plants leads to power generation costs at about the 1.5 to 2 times as for PV systems and the power plants are only feasible with large capacities which does not fit to the decentralized use of solar power plants.

Potential of solar radiation

The potential solar radiation relevant for photovoltaic power plants was evaluated by the NREL as shown in Figure 6.1.3-1 below.

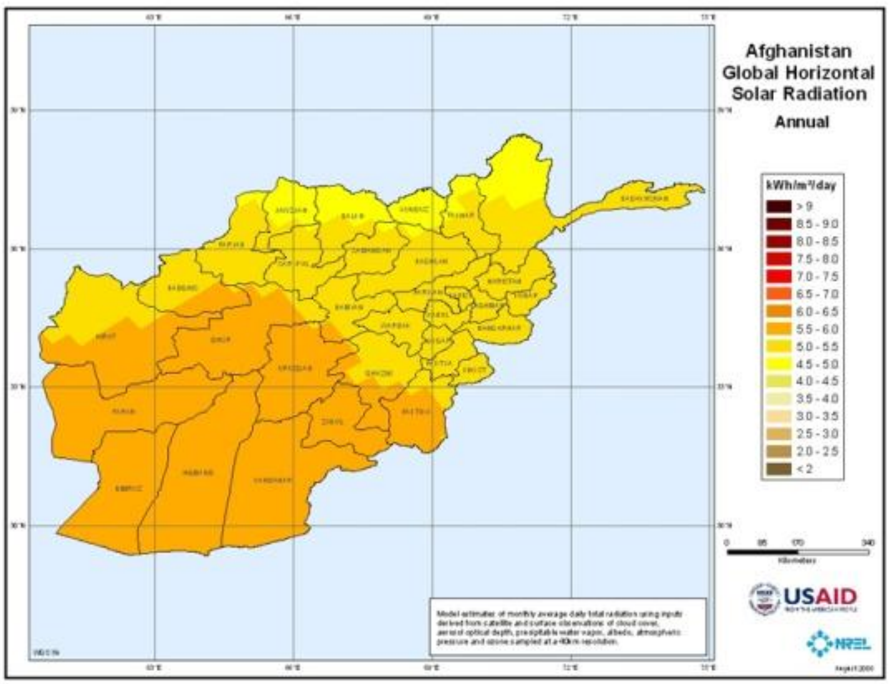


Figure 6.1.3-1: Global horizontal solar radiation map

The data provided by NREL [Available online: http://www.nrel.gov/international/ra_afghanistan.html] are taken as the main basis for this analysis.

From the global horizontal solar radiation, it can be estimated that the typical energy yield for a photovoltaic plant in Afghanistan is somewhere between 1485 and 1700 kWh/kW_p.

Photovoltaic power plants

A distinction must be made between large centralized facilities to supply electricity to the grid and small facilities that supply electricity to small island systems or individual consumers.

In the following table, the main technical – solar radiation, peak capacity and load factor – and economic data – CAPEX, operation and maintenance costs and lifetime – for large centralized photovoltaic power plants are presented for different regions in Afghanistan. The regions in the table headings refer to Annex 5.3.3-1.

Region		Nimruz IRAN	Herat IRAN	Herat TKM	Herat AFG	SEP	NEPS TKM	NEPS UZB	NEPS TAJ	NEPS AFG
Solar radiation	kWh/m²,a	1,700	1,700	1,485	1,700	1,700	1,485	1,485	1,485	1,485
Capacity	MWe	5	5	5	5	5	5	5	5	5
Load factor		0.194	0.194	0.170	0.194	0.194	0.170	0.170	0.170	0.170
CAPEX	US$/kW	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500
OPEX	%CAPEX/a	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Lifetime	a	20	20	20	20	20	20	20	20	20

Table 6.1.3-1: Main technical and economic data for large centralized photovoltaic power plants

It might also be worthwhile installing small solar power plants for decentralized electricity supply. This decentralized application provides many possibilities for supplying electricity in rural areas as well as in cities, especially in a hybrid system with a diesel generator or battery. In combination with a diesel generator, solar energy can replace in part the diesel fuel.

A comparison of typical decentralized systems with diesel only, a hybrid system consisting of diesel and photovoltaic, as well as a diesel and a small wind turbine is presented in the section below.

6.1.3.4 Wind

Potential of wind speeds

The potential for electricity generation by wind has been investigated by the NREL [Available online: http://www.nrel.gov/international/ra_afghanistan.html] and a study prepared by Tetra Tech for the Asian Development Bank (ADB) **[ADB_005]**. The Tetra Tech study, entitled "Development of Wind Energy Methodology and Engineering For Siting and Design of Wind Energy Projects in Afghanistan", is based on the NREL data. The wind speed map for a hub height of 50 m is presented in
Figure 6.1.3-2.

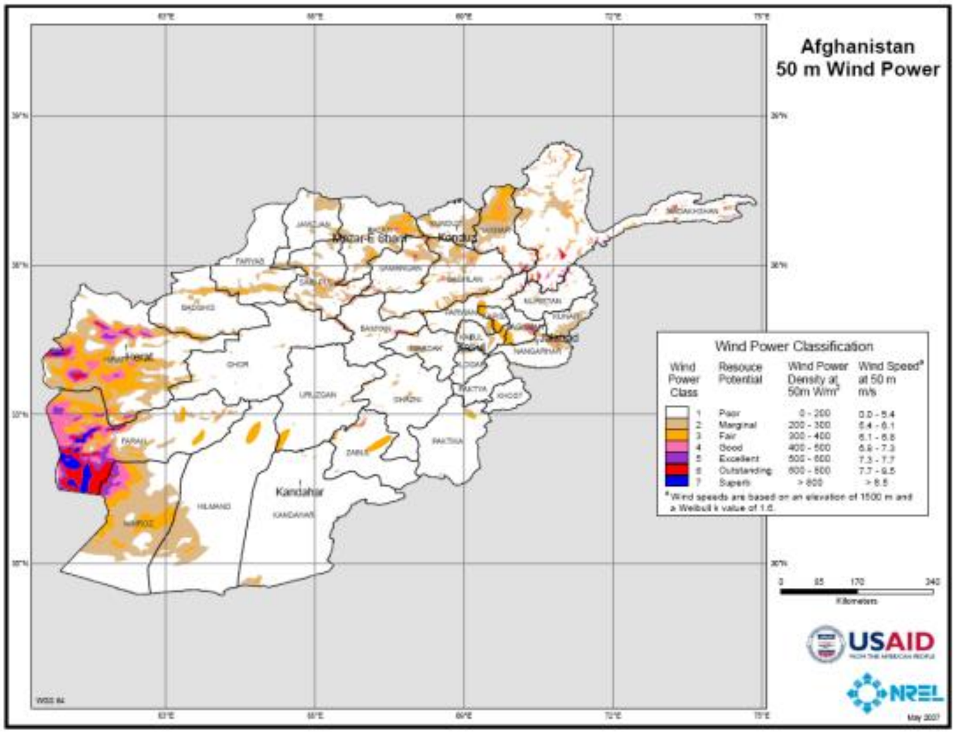


Figure 6.1.3-2: Wind speed map of Afghanistan (50 m height)

According to the “Afghanistan Rural Energy Strategy” [MIN_006 Afghanistan Rural Energy Strategy - p. 11] there is a theoretically maximum wind power generation capacity of 158 GW which could be developed.

Afghanistan shows significant potential for electricity generation from wind – especially the southwestern region. Nevertheless, up to now only very few small-scale wind turbines are in operation.

Wind power

A distinction must be made between large centralized facilities to supply electricity to the grid and small facilities that supply electricity to small island systems.

Regions with a wind speed of less than 6.5 m/s are not considered as potential candidates for wind farms. In the following table, the main technical – wind speed, rated capacity and load factor – and economic data – CAPEX, operation and maintenance costs and lifetime for an 8 MW wind farm are presented for different regions in Afghanistan. The regions in the table headings refer to **Annex 5.3.3-1**.

Region		Nimruz IRAN	Herat IRAN	Herat TKM	Herat AFG	SEP	NEPS TKM	NEPS UZB	NEPS TAJ	NEPS AFG
Mean wind speed	m/s	8.0	9.0	7.5	7.0					
Capacity	MWe	8	8	8	8					
Load factor		0.389	0.461	0.352	0.318					
CAPES	US$/kW	2,300	2,300	2,300	2,300					
OPEX	%CAPEX/a	3.5	3.5	3.5	3.5					
Life time	a	20	20	20	20					

Table 6.1.3-2: Main technical and economic data for an 8 MW wind farm

The data presented in **Table** 6.1.3-2 are based on a wind farm consisting of 10 Enercon E48 wind turbines with a hub height of 50 m and a rated power of 800 kW each. It is assumed that the wind farm is located at an altitude of 1250 m. The load factor includes total losses of 23% due to availability, wake losses and electrical losses.

Decentralized units with comparable small capacities can be applied to existing diesel generation assets to replace diesel fuel. These hybrid solutions are promising options to supply electricity for rural electrification or for small grids.

A comparison of typical decentralized systems with diesel only, a hybrid system consisting of a diesel and a small wind turbine, as well as a diesel and a photovoltaic system is presented in section below.

6.1.3.5 Decentralized power distribution systems

Considering the above-presented information, the most promising renewable energy sources for local generation in Afghanistan are solar (across the whole country) and wind (local). The following sections present some options for distributed electricity generation based on these sources. To cover as many remote areas as possible, the options presented here are not site-specific solutions, but solutions for generic sites. The calculations of the facilities are based on the following general assumptions:

- Two different sizes of remote villages are considered: one with 50 houses and one with 200 houses
- It is assumed that each household is composed of about 10 people
- The average annual electricity consumption per person is assumed to be 100 kWh/a (it is currently much lower, but this is likely to increase in future to the average levels presented for some already electrified towns)
- The CAPEXs for local distribution considered the following:
  Each household requires an electricity meter at a unit price of about $110
  Per household 50 m length cable is required, with unit costs of 12 $/m
  This results in total costs for household connection of 710 $/household.

The methodology applied for the following analysis is:

- A typical option for electricity generation in remote areas not connected to the electricity grid is a diesel generator. This option is calculated as a comparative case.

- For solar energy, two options are considered:
  - Solar home system
  - Hybrid system: photovoltaic and diesel
- For wind energy, a hybrid system of wind turbine and diesel generator is considered.

For the above-presented options, the average electricity generation costs are estimated at the level of the end user, which means that the costs of local distribution are also considered.

The economic parameters are based on the following assumptions:

- Diesel price: 1.3 $/l[1]
- Discount rate: 12%
- Loan duration: 10 years[2]

<u>Diesel generator</u>

This section presents a diesel generator as a typical option for electricity generation in remote areas. This system considers a central diesel engine and the construction of a local distribution network to connect all houses and institutions in the village.

The electricity generation costs calculated for this option and presented in the following table are used as comparative costs for the other options described in the following sections.

[1] It is assumed that this diesel price is about 30% higher than for central diesel power plants, as the diesel has to be transported to remote areas and theses costs have to be added.
[2] Compared to a central power generation plant, the loan duration is much shorter, as the life time of this equipment is also shorter.

Diesel generator	Unit	Figure	Figure
Connections		**50 Houses**	**200 Houses**
Number of persons / house		10	10
Electricity demand per person	kWh/person	100	100
Electricity demand per house	kWh/house	1,000	1,000
Electricity demand for whole village	kWh	50,000	200,000
Technical parameters			
Diesel - electrical capacity	kW	20	70
Diesel - electrical efficiency	%	30	35
Diesel - full load utilization hours	h/a	2,600	3,000
Energy balance			
Diesel - electricity generation	MWh/a	51	205
Fuel consumption	MWh/a	170	586
Diesel	1,000 l/a	17	59
Economical parameters			
Generation - Capital expenditure	US$	42,000	126,000
Local distribution - Capital expenditure	US$	35,500	142,000
Total capex	US$	77,500	268,000
Interest rate	%	12	12
Loan duration	a	10	10
Annuity factor	-	0.18	0.18
Diesel price	US$/l	1.30	1.30
Diesel - OPEX	US$ct/kWh	4.50	3.50
Electricity generation costs			
CAPEX - Generation	US$/a	7,433	22,300
CAPEX - Distribution	US$/a	6,283	25,132
OPEX (without fuel)	US$/a	2,295	7,175
Fuel	US$/a	22,030	75,903
Total	US$/a	38,042	130,509
Average electricity generation costs	**US$/MWh**	**746**	**637**

Table 6.1.3-3: Electricity generation costs for a diesel generator

From the above-presented results it is clear that there is an economy of scale using this technology for larger villages.

Solar home systems

One of the simplest applications of solar energy for electricity generation in local areas is a Solar Home System (SHS) for electricity generation in each house. The capacity of an SHS ranges from 30 Wp to 4000 Wp. These systems are highly suitable for small and dispersed villages (small number of houses with relatively large distances between houses), since they do not require any local distribution.

The main components of an SHS are the solar module(s), a battery, a charge controller and the loads (see Figure 6.1.3-3). The smallest SHSs are designed for lighting, e.g. a 50 Wp SHS can supply electricity for a 9 W compact fluorescent lamp for 12 hours.

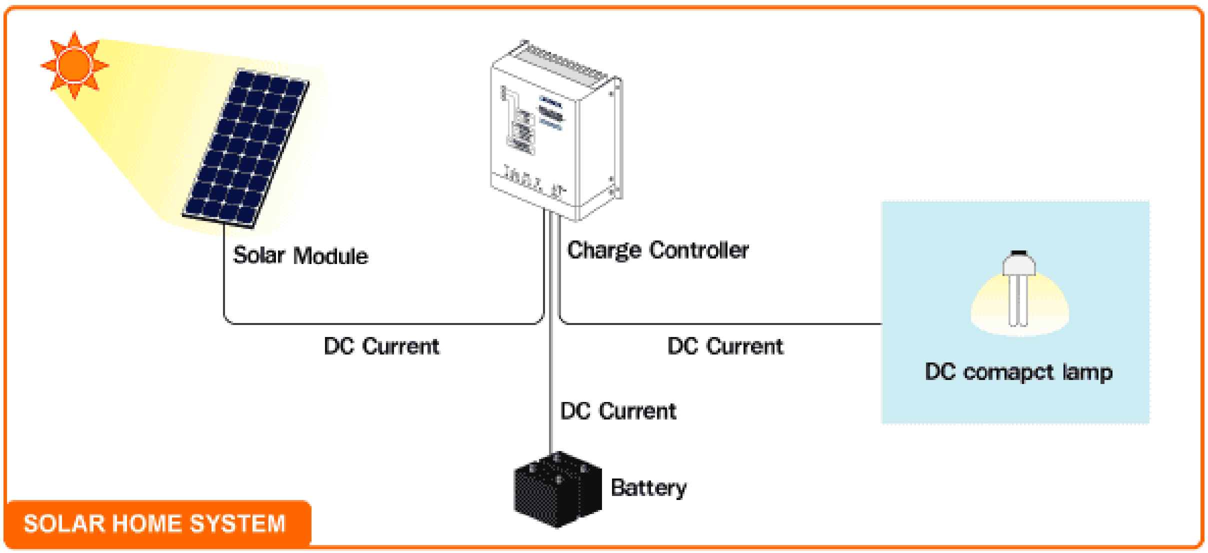


Figure 6.1.3-3: Solar Home System (source: www.leonics.com)

Larger SHSs are designed not only for lighting, but also for other appliances typical in a small-sized home. These systems also require an inverter (see Figure 6.1.3-4). For example, a 400 Wp SHS consisting of 8 x 50 Wp solar modules, 4 x 12 V 120 Ah batteries and a 1,000 W inverter can supply electricity for three fluorescent lamps (18 W), a radio, a fan, a TV and a 20 liter refrigerator.

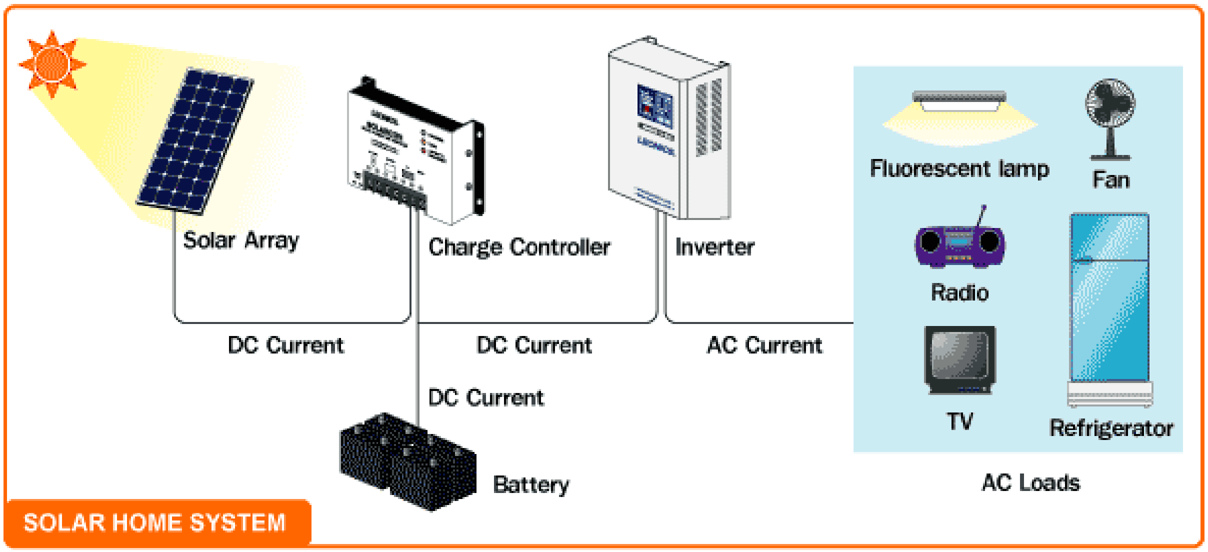


Figure 6.1.3-4: Large Solar Home System (source: www.leonics.org)

For a typical house, a 400 Wp SHS should be sufficient to cover the main electricity requirements (not only lighting), while larger systems of up to 4000 Wp could be used for large individual facilities, such as schools, health care centers, civil institutions, etc. Some of the advantages of these systems are easy installation, low maintenance and easy scale-up. Also, there are no distribution costs. Nonetheless, it must be noted that the initial capital costs are higher than for other technologies (e.g. hybrid systems with wind or PV).

PV Solar Home System			
	Unit	Individual Houses	Larger consumers
Technical parameters			
PV - electrical capacity	kW	0.4	4.0
PV - full load utilization hours	h/a	1,500	1,500
Energy balance			
PV - electricity generation	MWh/a	0.60	6.00
Economical parameters			
PV - Capital expenditure	US$/kW	5,500	5,000
Interest rate	%	12	12
Loan duration	a	10	10
Annuity factor	-	0.18	0.18
OPEX *	US$ct/kWh	13.00	13.00
Electricity generation costs			
CAPEX	US$/a	389	3,540
OPEX	US$/a	78	780
Total	US$/a	467	4,320
Average electricity generation costs	**US$/MWh**	**779**	**720**

* OPEX costs mainly consider replacement costs for the battery

Table 6.1.3-4: Electricity generation costs for standalone PV systems

The electricity generation costs calculated for these systems are independent of the installed capacity (no economy of scale for SHS). For individual houses, the electricity generation costs are slightly higher than those for the electricity generation costs based on a central diesel generator.

<u>Hybrid system: photovoltaic and diesel generator</u>

Since the capacity of the SHSs presented in the previous section is limited, for small and medium-sized villages (more than 30 houses) it is more suitable to consider the use of a central hybrid facility, which combines photovoltaic and diesel generation. Table 6.1.3-5 presents the main technical data of this system and the resulting electricity generation costs. Two important factors with an influence on electricity generation costs are the full-load operation hours and the CAPEX for the photovoltaic system. It should be noted that the costs of PV systems have fallen rapidly during the last four years. These examples assume an average of 1500 full-load hours and CAPEX of 2600 $/kW. Table 6.1.3-5 summarizes the main technical and economic data of the considered systems as well as the resulting electricity generation costs.

Diesel generator + PV modules	Unit	Figure	Figure
Connections		**50 Houses**	**200 Houses**
Number of persons / house		10	10
Electricity demand per person	kWh/person	100	100
Electricity demand per house	kWh/house	1,000	1,000
Electricity demand for whole village	kWh	50,000	200,000
Technical parameters			
Diesel - electrical capacity	kW	15	70
Diesel - electrical efficiency	%	30	35
Diesel - full load utilization hours	h/a	1,400	1,321
PV - electrical capacity	kW	20	75
PV - full load utilization hours	h/a	1,500	1,500
Energy balance			
Diesel - electricity generation	MWh/a	21	93
PV - electricity generation	MWh/a	30	113
Total - electricity generation	MWh/a	51	205
Fuel consumption	MWh/a	70	264
Diesel	1,000 l/a	7	26
Economical parameters			
Diesel - Capital expenditure	US$	31,500	126,000
PV - Capital expenditure	US$	52,000	195,000
Local distribution - Capital expenditure	US$	35,500	142,000
Total capex	US$	119,000	463,000
Interest rate	%	12	12
Loan duration	a	10	10
Annuity factor	-	0.18	0.18
Diesel price	US$/l	1.30	1.30
Diesel - OPEX	US$ct/kWh	4.50	3.50
PV - OPEX	US$/kW	25.00	25.00
Electricity generation costs			
CAPEX - generation	US$/a	14,778	56,812
CAPEX - distribution	US$/a	6,283	25,132
OPEX (without fuel)	US$/a	1,445	5,113
Fuel	US$/a	9,071	34,249
Total	US$/a	31,577	121,305
Average electricity generation costs	**US$/MWh**	**619**	**592**

Table 6.1.3-5: Electricity generation costs for hybrid systems consisting of photovoltaic and diesel generator

In these hybrid systems, PV acts as a fuel saver. Because of the high diesel prices, the combination of PV and diesel also saves money, as the electricity generation costs of these systems are 10% to 14% lower than those of a diesel generator alone.

The full-load hours of a PV system depend on the location. For Afghanistan, solar irradiation varies across the country and full-load hours of a PV system between 1200 and 1800 h/a can be assumed. This has an impact on the electricity generation costs of the hybrid system, as higher full-load hours of a PV system save more diesel. The influence of full-load utilization hours for a photovoltaic system can be seen in Figure 6.1.3-5. With increasing utilization hours, there is a significant fall in electricity generation costs.

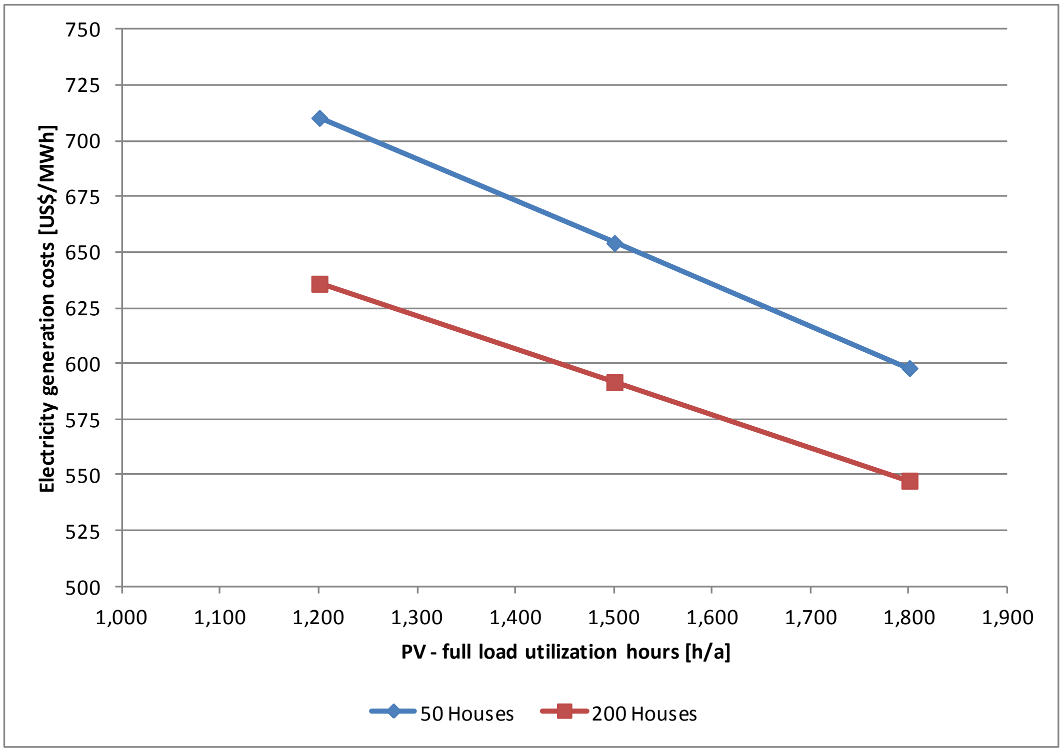


Figure 6.1.3-5: Sensitivity – full-load utilization hours for a PV/diesel hybrid system

As the capital cost of a PV system has changed greatly during the last few years, and also considering that the cost of a PV system in remote areas is usually higher than the world market price, a sensitivity analysis for varying PV system CAPEX has also been performed. Figure 6.1.3-6 presents the dependency between CAPEX and electricity generation costs. Lower CAPEX on photovoltaic systems, which is expected to be the case in the medium term, can significantly reduce the electricity generation costs of such a hybrid system.

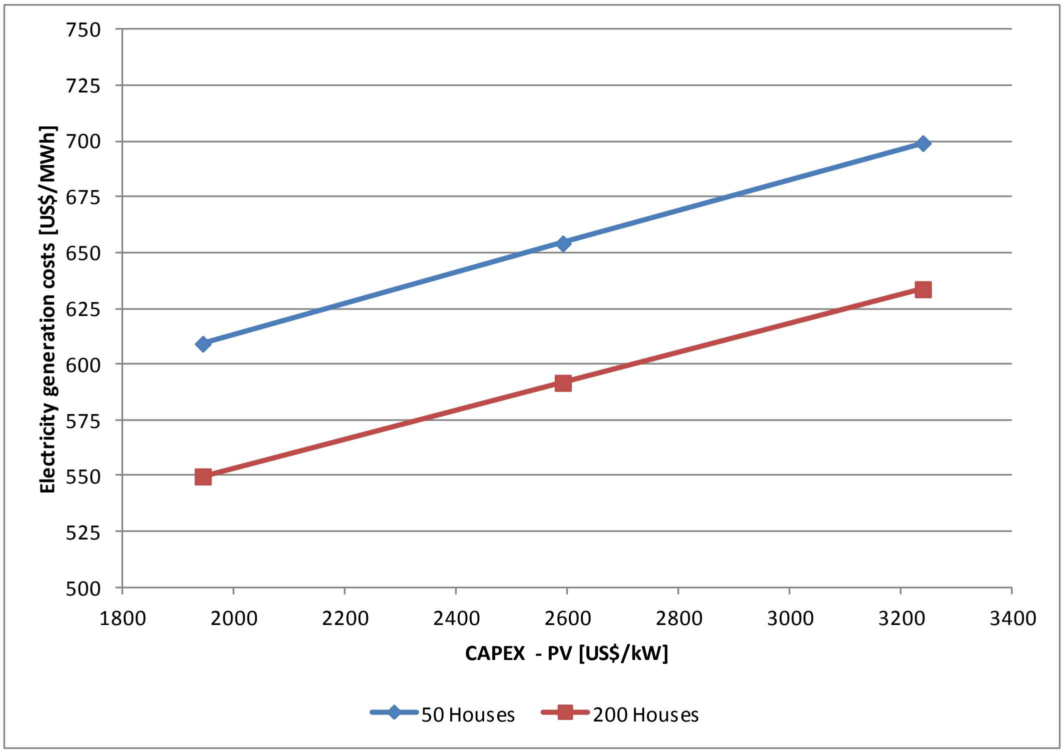


Figure 6.1.3-6: Sensitivity - CAPEX on a PV/diesel hybrid system

Hybrid system: wind turbine and diesel generator

As an example, a hybrid system consisting of a diesel generator and a wind turbine is presented below, although it must be kept in mind that the wind conditions at a specific site will have a huge influence on the technical and economic feasibility of a facility. The main technical data and resulting electricity generation costs of this system are presented in Table 6.1.3-6. The following calculations assume an average of 2200 full-load utilization hours for the wind turbine.

Diesel generator + wind turbine	Unit	Figure	Figure
Connections		**50 Houses**	**200 Houses**
Number of persons / house		10	10
Electricity demand per person	kWh/person	100	100
Electricity demand per house	kWh/house	1,000	1,000
Electricity demand for whole village	kWh	50,000	200,000
Technical parameters			
Diesel - electrical capacity	kW	20	70
Diesel - electrical efficiency	%	30	35
Diesel - full load utilization hours	h/a	350	414
Wind - electrical capacity	kW	20	80
Wind - full load utilization hours	h/a	2,200	2,200
Energy balance			
Diesel - electricity generation	MWh/a	7	29
Wind - electricity generation	MWh/a	44	176
Total - electricity generation	MWh/a	51	205
Fuel consumption	MWh/a	23	83
Diesel	1,000 l/a	2	8
Economical parameters			
Diesel - Capital expenditure	US$	42,000	133,000
Wind - Capital expenditure	US$	74,000	264,000
Local distribution - Capital expenditure	US$	35,500	142,000
Total capex	US$	151,500	539,000
Interest rate	%	12	12
Loan duration	a	10	10
Annuity factor	-	0.18	0.18
Diesel price	US$/l	1.30	1.30
Diesel - OPEX	US$ct/kWh	4.50	3.50
Wind - OPEX	US$ct/kWh	3.20	3.20
Electricity generation costs			
CAPEX - generation	US$/a	20,530	70,263
CAPEX - distribution	US$/a	6,283	25,132
OPEX (without fuel)	US$/a	1,723	6,647
Fuel	US$/a	3,024	10,737
Total	US$/a	31,560	112,779
Average electricity generation costs	**US$/MWh**	**619**	**550**

Table 6.1.3-6: Electricity generation costs of a hybrid system consisting of wind turbine and diesel generator

The electricity generation costs of the hybrid system are almost 20% lower than those of a diesel generator.

The influence of the full-load utilization hours for the wind turbine can be seen in Figure 6.1.3-7. With increasing utilization hours, there is a significant fall in electricity generation costs.

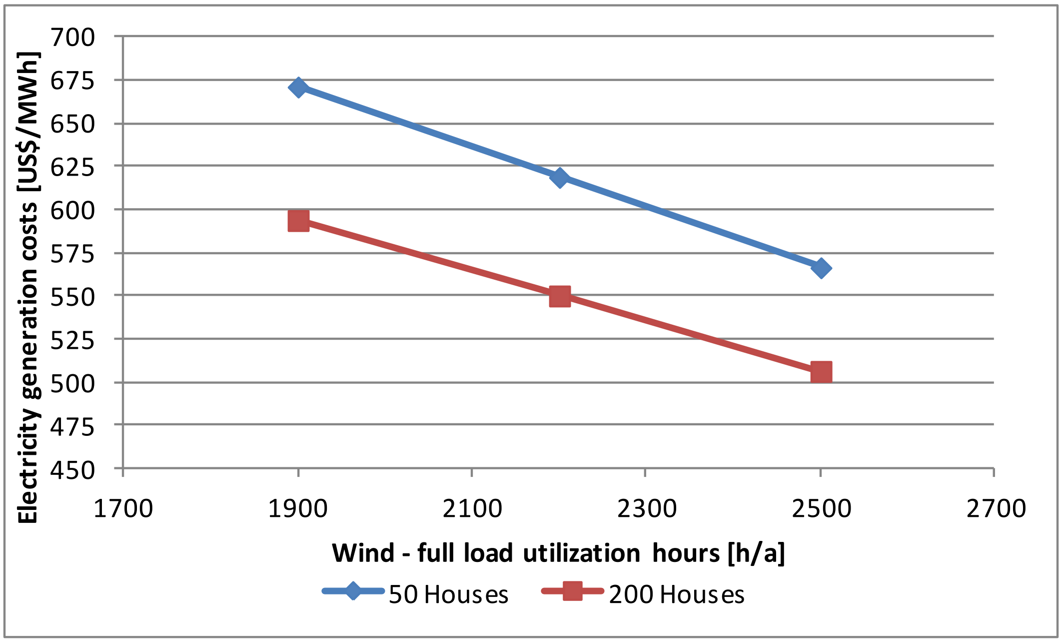


Figure 6.1.3-7: Relationship between full-load utilization hours and electricity generation costs for a wind/diesel hybrid system

At a site with favorable wind conditions, a hybrid system of wind and diesel has a huge potential for electricity generation costs much lower than the costs of a standalone diesel generator.

<u>Comparison of electricity generation costs</u>

The following tables show a summary of the main technical data as well as the electricity generation costs of the different systems for remote villages with 50 and 200 houses as presented in the previous sections.

		Diesel only	Diesel + Wind	Diesel + PV	SHS*
Technical data					
Diesel generator	kW	20	20	20	
Wind generator	kW		20		
PV generator	kW			20	
Energy balance					
Diesel generator	MWh/a	51	7	21	
Wind generator	MWh/a		44		
PV generator	MWh/a			30	
Total	**MWh/a**	**51**	**51**	**51**	
Costs					
Total costs	US$/a	38,042	31,560	33,436	
Average electricity generation costs	**US$/MWh**	**746**	**619**	**656**	**779**

* Solar Home Systems are installed independently for each house

Table 6.1.3-7: Electricity generation costs of different systems for remote areas - village with 50 houses

		Diesel only	Diesel + Wind	Diesel + PV	SHS*
Technical data					
Diesel generator	kW	70	70	70	
Wind generator	kW		80		
PV generator	kW			75	
Energy balance					
Diesel generator	MWh/a	205	29	93	
Wind generator	MWh/a		176		
PV generator	MWh/a			113	
Total	**MWh/a**	**205**	**205**	**205**	
Costs					
Total costs	US$/a	130,509	112,779	121,305	
Average electricity generation costs	**US$/MWh**	**637**	**550**	**592**	**779**

* Solar Home Systems are installed independently for each house

Table 6.1.3-8: Electricity generation costs of different systems for remote areas - village with 200 houses

From the information presented in the previous sections and on the basis of the selected economic parameters, it can be concluded that:

- A solar home system for each individual house is still the most expensive form of electrification for remote areas.
- For a centralized village system, the standalone diesel generator is the most expensive solution.
- A combination of diesel and renewable energy (wind or solar) substitutes diesel and saves money.

- The most promising renewable energy source for cost reduction is wind. A hybrid system with wind and diesel should be the preferred option - if possible. Otherwise, the use of solar energy (PV) as a diesel fuel saver can also be recommended.
- The use of wind or solar energy must be specifically investigated for each project site.

It is important to keep in mind that, according to the available information for Afghanistan, wind conditions vary greatly across the country. Therefore, the use of a hybrid wind/diesel system cannot be seen as a general solution for the electrification of remote areas.

It has to be mentioned that the measures for improvement of the distribution system taken up to now were successful. Anyhow it is necessary to keep the momentum and to increase the efforts to expand the distribution system to reach the goal of high connection rate within Afghanistan.

6.2 Options for Import

During the inception phase and data collection, various sources of power imports were identified, together with the intent of the exporting countries to wheel electricity through Afghanistan to Pakistan.

According to figures provided by AEIC, Afghanistan imported 73% of its total electrical energy demand in 2011. The shares attributed to source countries are as follows. The largest contributors are Iran (22%) and Uzbekistan (57%). Imports from Tajikistan and Turkmenistan were reported as 16% and 4% of total demand.

The present transmission system for imports is operated at its limit and especially the transmission line via the Salang Pass from the north for feeding the Kabul region represents a bottleneck for imports from Uzbekistan, Tajikistan and Turkmenistan.

In general, the exporting countries intend to at least retain their power transfer at present levels or even increase it.

<u>Import from Turkmenistan:</u>
With the ongoing Turkmenistan - Afghanistan interconnection project, an additional importing capacity of 300 MW will be available after erection of the new HV interconnection line. Network developments within Turkmenistan and their proposed design of 500 kV for the interconnection indicates that for, long term planning, additional power up to the capacity of a 500 kV line will be available for import from Turkmenistan.

<u>Import from Uzbekistan:</u>
Currently Uzbekistan is providing the major share of imported power for Afghanistan and is operating its existing 220 kV double-circuit line at its limit.
Increases of imports from Uzbekistan will only be possible by increasing the transfer capacity by erection of new transmission lines.

There is no information on projects for the expansion of transmission capacity and it is therefore assumed that the import from Uzbekistan will remain constant at the current level.

Import from Tajikistan:
The import capacity from Tajikistan has been significantly increased by the recent putting into operation of the 220 kV double-circuit line from Sangtuda to Pul-e-Chomri.

Electricity generation in Tajikistan is dominated by hydro power, so Tajikistan is able to provide a spring and summer surplus for export to Afghanistan. The network design and specifically the limited transfer capacity via the Salang Pass has so far prevented higher imports from Tajikistan.

Furthermore, asynchronous operation of the Uzbek and Tajik power systems currently prevents supplementing thermally generated power from Uzbekistan by hydro power from Tajikistan during spring and summer.

If the technical limitations within the Afghan transmission network were to be eliminated, Tajikistan could use the available transmission capacity of the interconnection line for exporting its summer surplus to Afghanistan.

Import from Iran:
Iran exports to the neighboring Afghan provinces Farah and Nimroz at 132 kV and lower voltage levels. The Iran exporting system is not connected to any other Afghan power system.

There is no information on projects for increasing imports from Iran, but it is assumed that in the course of expanding the market for energy exchange, Iran will be ready to deliver more energy to Afghanistan.

6.3 Options for Transmission System Expansion

With regard to the development of the Afghanistan transmission system, there are several projects under consideration for the improvement of power imports to the system and for the connection of network segments within Afghanistan. Details of major transmission projects, such as:

- new Turkmenistan to Afghanistan interconnector
- additional Hindu Kush crossing
- NEPS to SEPS interconnector
- connection to Pakistan
- Herat interconnector
- CASA-1000

are discussed in the following sections.

6.3.1 General

For planning purpose the general design of major components are given in the following. For cost estimation unit costs were take as basis for an overall cost estimation. It has to be pointed out that accuracy of the cost estimation can only meet the requirements for the project definition phase.

6.3.1.1 Transmission lines

For the transmission systems in the region, the standard voltage levels of 220 kV and 110 kV are used in Afghanistan and furthermore 500 kV is used in the neighboring transmission systems of Turkmenistan, Uzbekistan and Tajikistan.

- The 500 kV lines are constructed using single-circuit towers and conductor types ACSR 300 or ACSR 400 with three conductors per phase.
- The 220 kV lines are single-circuit or double-circuit types but mainly using only one conductor per phase. The conductor types used are ACSR 300 or ACSR 400.
- The 110 kV lines are constructed as single-circuit or double-circuit lines equipped with a single conductor per phase of types ACSR 120, ACSR 150 and ACSR 185.

The transmission line types currently used in Afghanistan are listed in subchapter 5.3.
For expansion planning, the Consultant recommends stipulating a set of standardized designs that should be used for further expansion of the network.

On the 110 kV level, the main design currently used is the single-circuit single-conductor line with ACSR 185 conductors (1x3x1xACSR185).

For the 220 kV level, the lines are designed as single-circuit or double-circuit lines either with single conductors ACSR 300 (1x3x1xACSR300, 2x3x1xACSR300) or with double-bundle conductors ACSR 300 (1x3x2xACSR300, 2x3x2xACSR300).

As yet, there is no 500 kV transmission level in the Afghan system. The 500 kV lines in the neighboring countries are designed according to the former Russian standard as single-circuit lines with triple bundle conductor using ACSR300 or ACSR400 conductors (1x3x3xACSR300 or 1x3x3xACSR400).
For major transmission corridors with expected significant increase of transmission capacity in future development it may be necessary to construct double circuit lines with only one circuit strung in the initial phase.

In general, for the transmission capacity, various values can be defined. There are the commonly used values of natural capacity and thermal capacity. Beside these, an economic transmission capacity is defined as 20% higher than the natural capacity of the line.

The following Table 6.3.1-1 gives the calculated values of the transmission capacities for the different line types:

Voltage / line type	Conductor type	Capacity [MVA] natural	economic	thermal
500 kV				
single circuit	1x3x3xACSR300	890	1070	1800
single circuit	*1x3x3xACSR400*	*900*	*1080*	*2200*
double circuit	2x3x3xACSR300	1780	2140	3600
double circuit	*2x3x3xACSR400*	*1800*	*2160*	*4400*
220 kV				
single circuit	1x3x1xACSR300	120	140	270
single circuit	*1x3x1xACSR400*	*135*	*160*	*320*
double circuit	2x3x1xACSR300	240	280	540
double circuit	*2x3x1xACSR400*	*270*	*325*	*640*
110 kV				
single circuit	*1x3x1xACSR185*	*45*	*55*	*97*

Table 6.3.1-1: Transmission capacity for various line types

For the region of Central Asia, the following unit costs for the transmission network expansion and reinforcement are expected:

500 kV single circuit 1x3x3xACSR400 0.380 $m/km
500 kV double circuit 2x3x3xACSR400 0.585 $m/km
220 kV single circuit 1x3x1xACSR400 0.230 $m/km
220 kV double circuit 2x3x1xACSR400 0.350 $m/km
110 kV single circuit 1x3x1xACSR185 0.120 $m/km

For construction of a double circuit line with one circuit installed costs are estimated with 80% of the costs for construction of the complete line. For stringing the second circuit the remaining 20% of the total costs are considered.

For some sections bundle conductors on 220 kV lines were considered and we estimate for this design the following unit costs
220 kV single circuit double bundle 1x3x2xACSR400 0.330 $m/km
220 kV double circuit double bundle 2x3x2xACSR400 0.502 $m/km

For construction of a transmission line in mountain areas the costs are increasing. Within our cost estimation we considered a factor of 1.3 for difficult mountain areas.

6.3.1.2 Substations

For the substations, too, a standard design for each voltage level will be considered for the planning. The existing substations on the 220 kV and 110kV levels are outdoor switchyards using air-insulated technology.

The Consultant recommends continuing with the use of this technology for the power system expansion, as long as there is enough space for erection of the substations or for substation expansions.

The capacity of the interbus transformer within the substations will be selected to cover the load which is allocated to the substation within the planning horizon. In general, development will start with one installed transformer but with sufficient spare space in the substation for a second transformer of the same size to be installed at a later stage to improve security of supply at substation level. For the interbus transformer, standard types will be used.

In the latest investments in the transmission system, substations stepping down from 220 kV to 20 kV level were used. This is to be recommended in regions where the population is concentrated in a certain area and a further spread into rural areas is not expected. For regions with dispersed settlements, a subtransmission level of 110 kV will be necessary for transmission of the power from central in-feed points in the regions.

Expansion of the transmission system will require expansions of existing substations as well as construction of new substations, or adding a higher voltage level to existing substations.

For the purpose of the master plan, a detailed design for each substation and substation expansion, which would be required for a detailed cost estimate, is not prepared. For this reason, estimates of the cost totaling up to the major component of the feeders were prepared on the basis of a generic substation design.

For expanding an existing substation with an additional feeder, the following costs are estimated under the condition that there is sufficient spare space within the existing substation and buildings:

expansion of substation with one new 500 kV bay 3.30 $m
expansion of substation with one new 220 kV bay 0.90 $m
expansion of substation with one new 110 kV bay 0.54 $m

For erecting a new substation, the complete civil works (leveling, fencing, etc.) have to be considered, which will depend on the size and voltage level of the substation. For a new substation, we allocated the costs over the number of HV feeders with the following estimations of substation costs:

	Cost for new substation					
Number of feeders	**3**	**4**	**5**	**6**	**7**	**8**
500 kV	14.8 $m	18.0 $m	21.3 $m	24.5 $m	27.8 $m	31.1 $m
220 kV	6.5 $m	7.0 $m	7.4 $m	7.8 $m	8.2 $m	8.6 $m
110 kV	3.5 $m	3.7 $m	3.9 $m	4.1 $m	4.3 $m	4.5 $m

Table 6.3.1-2: Estimated costs for new substations

For cost estimation of a step-down transformer within the new substations, specific costs based on installed transformer capacity are used. Transformers of higher capacity will have less specific costs than smaller transformers. The transformer costs will range between 19,000 $/MVA and 21,000 $/MVA.

In the cause of the power system study for the optimized generation expansion reactive power compensation equipment at several location of the power system were added to improve voltage condition within the network. Cost for compensation equipment differs by type and voltage level on which the equipment has to be implemented. We are using simplified estimation of 20,000 $/MVAr for each type independent of the voltage level.

6.3.1.3 Back-to-back stations

For connecting systems that are operating asynchronously, HVDC back-to-back stations are necessary. The expression back-to-back indicates that the rectifier and inverter are placed in the same station. HVDC back-to-back stations can be built using two technologies: line-commutated converters (LCC or classic technology) or self-commutated converters (VSC technology).

For Afghanistan, which currently has only small sources of short-circuit power, only the HVDC back-to-back systems using VSC technology are feasible with a reasonable technical outlay.

The CAPEX for an HVDC back-to-back station depends on the power to be transmitted and the voltage level of the AC systems to be connected. The price is based on ongoing projects implemented in 2012 in classical technology. Our estimate considers about 20% additional costs for applying VSC technology.

500 kV/500 kV back-to-back station:	0.38 $m/MW
220 kV/220 kV back-to-back station:	0.33 $m/MW

The operation and maintenance of HVDC back to back station requires highly skilled staff, auxiliary services and well operating logistics for the supply and stocking of spare parts for this technology. This will be essential for the reliable use of this technology.

Erecting of the back to back stations at different locations will multiple the demand for qualified staff which may not be available in Afghanistan.

Major part of the O&M costs are labor costs and the cost for spare parts and this will be doubled in case of having two locations. Furthermore the multiple use of auxiliary facilities will not be possible in case of decentralist installation of the back to back stations.

Therefore it is recommended to create a centralized back to back hub at one location

6.3.1.4 Review of Afghan expansion plan

During the inception meeting held in Istanbul from 24 to 26 April 2012, the network expansion plan prepared by MEW was provided (see **Annex 6.3.1-1**). The map shows the existing transmission lines and substations, the substations and transmission lines under construction, and the planned transmission line expansions and new substations for priority 1 and priority 2.

The overall planning shows the concept of connecting the existing network segments via a ring structure of transmission lines. The major transmission lines identified in the Afghan expansion plan are:

- 500 kV line Turkmenistan - West Kabul
- 500 kV line West Kabul - Kandahar (NEPS - SEPS interconnector)
- 500 kV line Andkhoy - Herat
- 220 kV line Herat - Kandahar.

Connection of additional substations in remote provinces is planned with spur lines from the main ring. Furthermore, a line connecting Naghlu HPP to the new Jablisraj (Charikar) substation to create a ring around the Kabul area is envisaged in the Afghan planning.

It is planned to connect most provinces to the national grid by constructing transmission lines and at least one HV substation per province.

This planning is based on the assumption of possible synchronized operation of the Afghan system together with all in-feeding systems aiming at an integrated network in Afghanistan. The planning did not consider the current asynchronous operation of the in-feeding systems.

The Afghan Energy Information Center is also publishing a power system expansion plan, AEIC web site [AEIC_011]. The planning for the NEPS system is, in its major parts, consistent with the planning provided by MEW.

The ongoing planning driven by USAID for the NEPS - SEPS interconnector is based on a 220 kV design for the transmission line which is not consistent with the MEW planning for a 500 kV design.

The result of the optimization process and the power system study for the Power Sector Master Plan indicates the need of revision of parts of the planning provided by MEW. The voltage level for the required network expansion for the NEPS to SEPS interconnector and the Andkhoy - Herat line was investigated in cause of the optimization and power system calculations. Furthermore some details on the network development within the provinces were revised.

6.3.1.5 Connection of Turkmenistan and Tajikistan

At present, Tajikistan is offering surplus power from hydro generation, available during spring and summer, for export to Afghanistan.

The Tajik power system is linked via a 220 kV double-circuit line to Pul-e-Chomri. During winter, Tajikistan faces a power deficit and is seeking options to balance the high winter demand during the period of low power generation by their own hydro power plants.

One option is to import power generated by thermal power plants in Turkmenistan and a possible transmission corridor in north Afghanistan would be the backbone for importing power from Turkmenistan to Pul-e-Chomri Substation. The existing 220 kV double circuit line would then be used for transmission of the power to Tajikistan.

A check of technical feasibility and identification of any additional measures needed to ensure secure and stable network operation is included in the power system analysis.

6.3.2 New Turkmenistan to Afghanistan Interconnector

In parallel with the Afghanistan Power Sector Master Plan, technical assistance TA -7853 (REG) Afghanistan and Turkmenistan Regional Power Interconnection Project is ongoing.

This project is in the pre-feasibility phase and includes, beside the expansion of generation capacity in Turkmenistan, the increase of exports to Afghanistan.

Ongoing network reinforcement within Turkmenistan will create a strong starting point for an interconnection line at Atamyrat Substation about 150 km from the Turkmen - Afghan border. The substation at Atamyrat will be expanded by adding new 500 kV and 220 kV switchgear and expansion of the 110 kV substation.

According to information from Turkmenenergo (TE), the transmission line project from Atamyrat to the Afghan border has already been contracted with a 500 kV single-circuit line design using triple bundle ACSR400 conductors, and completion is expected in 2013.

The crossing point at the border has already been agreed between Turkmenistan and Afghanistan.

The issue of continuing the export line from the AFG border to a suitable connection point within the Afghanistan network has been handled in the course of processing the Afghanistan Power Sector Master Plan project, considering the following key points:

- the additional generation capacity for export to Afghanistan will be 300 MW
- up to the Afghan border, a 500 kV line will be used
- the starting point for the interconnection line will be the new Atamyrat 500/220/110 kV substation
- synchronization problems and operation philosophy.

In principle, it can be stated that for transmitting 300 MW, a voltage level of 220 kV would be sufficient. The length of the 500 kV line between the Afghan border and Andkhoy will be only about 40 km but construction of a 220 kV line along that section would be a dead end for further development. A higher voltage level of 500 kV would be required for transfer of more than 700 MW, with the requirement for transfer capacity depending on the expected load to be fed from Turkmenistan and the possibilities of further export and onward transmission.

For this reason, transmission system expansion in Afghanistan should offer a flexible solution with the possibility for further upgrading of transmission capacity. Such a solution was already presented during the inception meeting in Istanbul and the adapted phased development of the new Turkmenistan to Afghanistan interconnection system is outlined below. This proposal includes system reinforcement for additional imports and exports.

The initial stage of the interconnection is covered by the ongoing Regional Power Interconnection Project, which considers construction of a 500 kV single-circuit line from the border via Andkhoy to Sheberghan. In an initial phase, this line will be operated on the 220 kV level and will feed the new Andkhoy 220/110 kV Substation and the new Sheberghan 220/110 kV Substation.

The desktop study for the line routing for this section from the border to Sheberghan was carried out under the Regional Power Interconnection Project and the overview drawing is attached in **Annex 6.3.2-1**.

Further connection between Sheberghan and Mazar-i-Sharif will be realized by construction of a new 220 kV double circuit line from Mazar-e-Sharif to Sheberghan along the existing 110 kV corridor.

6.3.2.1 Conclusion and stages for the new Turkmenistan to Afghanistan Interconnector

Atamyrat will be the 500/220/110 kV substation in Turkmenistan, which is designated as the starting point of the Turkmenistan to Afghanistan interconnector. Turkmenistan has already taken steps to strengthen the 500 kV network between Mary and Atamyrat and to construct the 500 kV transmission line to the border with Afghanistan.

Currently, the electrical grid in the northwest region of Afghanistan is operated in islanded mode with a single source from the existing 110 kV import line from Turkmenistan. The increasing number of consumers connected to that import line in the provinces of Faryab, Jowzjan and Sar-e Pol is causing overloading of the line. Transfer on the line is reaching the limit of voltage stability.

However, demand and connections will further increase in that region and expansion of the network will present an opportunity to connect additional loads in Balkh. In later expansion stages, it will also be possible for loads in Herat province to be supplied from the substations in Faryab province.

Expected demand growth in Afghanistan is presented in the section “Demand Forecast”. Provinces with high load expectations are Kabul, Herat, Balkh and Kandahar. Besides the supply of the province, which covers the landing point of an infeed line, wheeling of the power to other load centers is also an important issue in the power sector master plan.

The expected peak demand for the provinces in the northwest of Afghanistan up to 2032 is given in **Table 6.3.2-1**. The column “Possible supply from TKM infeed” indicates the peak demand within the current configuration and from 2015 onwards, assuming that Balkh province will also be connected to the northwest region.

Year	Faryab	Jowzjan	Balkh	Sar-e Pol	Possible supply from TKM infeed
2010	17.8	10.8	(40.4)	2.6	31.1
2011	19.8	10.7	(51.1)	3.1	33.5
2012	23.1	12.5	(56.2)	5.5	41.0
2013	26.7	14.4	(60.9)	8.1	49.1
2014	30.6	16.4	(66.1)	10.9	57.9
2015	34.8	18.7	71.6	14.5	139.6
2016	39.4	21.1	77.6	18.1	156.2
2017	44.4	23.7	84.2	21.8	174.2
2018	47.8	25.4	89.8	23.6	186.6
2019	51.3	27.2	95.2	25.4	199.1
2020	55.0	29.0	100.7	27.3	212.0
2021	57.0	30.2	106.4	29.9	223.5
2022	60.7	32.1	113.1	32.8	238.7
2023	64.3	33.9	119.5	35.9	253.6
2024	67.7	35.6	125.5	39.4	268.2
2025	71.3	37.5	131.9	43.0	283.7
2026	75.0	39.4	138.6	45.7	298.7
2027	79.0	41.4	145.8	48.5	314.7
2028	76.2	39.9	140.3	46.3	302.7
2029	80.0	41.9	147.3	48.2	317.4
2030	84.1	43.9	154.5	50.2	332.7
2031	88.3	46.1	162.1	52.3	348.7
2032	92.6	48.3	169.9	54.4	365.3

Table 6.3.2-1: Forecast for peak demand in northwest region of Afghanistan

If Herat is also supplied from substations in Faryab, the peak load for this region will be at least doubled. For the expected load of 365 MW, or about 800 MW if Herat is connected to Faryab, it is obvious that the currently used voltage of 110 MV will not be sufficient for further network development.

Besides the infeed from Turkmenistan, construction of a gas-fired power plant at Sheberghan will be a possible source of power supply in that region and network development will have to provide the possibility of connection of Sheberghan power plant with 200 MW.

The ongoing project in Turkmenistan for additional generation capacity for export to Afghanistan will be the first additional power source to cover growing demand in Afghanistan. Initially, the additional import capacity will be 300 MW with the possibility of significant growth up to 1000 MW.

The nearest consumers are those located in the northwest at the border with Turkmenistan. The first phase of the interconnection project will be to increase the infeed to the currently isolated network in the northwest. However, the prospect is to supply the load centers in Kabul and Kandahar / south Afghanistan.

A staged development of the network with maximum use of each development stage was elaborated. All the CAPEX fits into the optimized future development for the network. At the same time, the phasing plan accommodates the immediate need for additional power sources for supplying the load centers and the limited funding possibilities in the near term.

The stages for development of the Turkmenistan - Afghanistan interconnector take account of the following constraints:

- The power supply at the 110 kV level is not appropriate for further network development.
- Use of 220 kV for the new import line will be appropriate for the first 300 MW.
- Considering the potential increase in additional generation capacity within Turkmenistan allocated for export, the 500 kV level is justified for network development.
- On Afghan territory, the interconnection line will be constructed as a 500 kV line.
- Transmission capacity across the Hindu Kush will be increased by an additional transmission line.
- Growth in demand is expected according to the base case of the updated demand forecast presented in the section “Demand Forecast”.

<u>Development Stage A up to 2015:</u>
For stage A, it is assumed that up to 300 MW will be available to serve the northwest region of Afghanistan. Network development should be carried out with low CAPEX while ensuring suitability for further development.

Development in stage A will comprise the following details:

(i) Erection of Andkhoy substation 220/110 kV with interbus transformer 220/110 kV with a capacity of 50 MVA to serve Faryab province’s demand and construction of a 500 kV line from the border with Turkmenistan to a new 220/110 kV substation at Andkhoy with a line length of about 40 km.
Due to the expected initial load of about 150 MW in the northwest region, operation of the line at the 220 kV level will be sufficient.

(ii) Erection of Sheberghan substation 220/110 kV with interbus transformer 220/110 kV with a capacity of 50 MVA to serve the demand of Jawzjan and Sar-e Pul provinces and construction of a 500 kV line from the 220/110 kV substation at Andkhoy to the new 220/110 kV substation at Sheberghan with a line length of about 70 km.
This line will later also be a part of the bulk transmission line to Pul-e-Chomri. The line will be operated initially at the 220 kV level.

(iii) Construction of a 220 kV line from Sheberghan to Mazar-e-Sharif, line length about 140 km. This line will use double circuit towers with initially one circuit installed, because this line section will be required for bulk power transport from Sheberghan TPP.

This configuration will allow the feeding of loads in the provinces of Faryab, Jowzjan, Sar-e Pul and Balkh with an expected demand for those four provinces of 140 MW in 2015, growing to 365 MW in 2032, as shown in **Table 6.3.2-1**.

The estimated costs for development stage A come to a total of about $106.5m.

T_01_A						
Measure	Type	No	[MVA]	[km]	Cost	
new substation Andkhoy	220kV	3			6.5	$m
expansion substation Andkhoy	110kV	1			0.5	$m
transformer Andkhoy	220/110kV	1	50		1.0	$m
new substation Sheberghan	220kV	3			6.5	$m
expansion substation Sheberghan	110kV	1			0.5	$m
transformer Sheberghan	220/110kV	1	50		1.0	$m
expansion substation Mazar-e-Sharif	220kV	1			0.9	$m
500kV line TKM-Border - Andkhoy	1x3x3xACSR400			40	15.2	$m
500kV line Andkhoy - Sheberghan	1x3x3xACSR400			70	26.6	$m
220kV line Sheberghan - Mazar-e-Sharif first circuit	2x3x2xACSR300			140	47.7	$m
Subtotal T_01_A					106.5	$m

Table 6.3.2-2: CAPEX details for Stage A of Turkmenistan - Afghanistan interconnector up to 2015

Construction of the 500/110 kV substation at Andkhoy or Sheberghan without introduction of the 220 kV level is not recommended for the following reasons:

- 500 kV level is not required in the first development stage
- 220 kV level is required for further development of the transmission system in the northwest of Afghanistan
- This would force CAPEX in the 110 kV network, which is not appropriate for further development.

Development Stage B up to 2020:

Development stage B of the new Turkmenistan to Afghanistan interconnector project and stage A of the Hindu Kush crossing project will enable the operation of a national grid with all Afghan generation units synchronized.

Compared to islanded operation, the primary benefits of operation of a unified national grid are a significant increase in the security of power supply; power sources can be used to their maximum availability; reserve generation capacity can be shared across the whole network and load shedding can thus be reduced.

Due to the fact that the power systems of TKM, UZB and TAJ, which feed into Afghanistan, operate in asynchronous mode, connection of the infeed lines to the Afghan national grid requires HVDC back-to-back converter stations.

These back-to-back stations can be installed either at the border to the respective system or at the receiving end of the interconnection lines at a central point.
Installation at the border or the first substation in Afghanistan along the interconnection line will distribute the installation to three different locations. The operation and maintenance of back-to-back stations requires highly qualified staff, which may not be available in the quantity required for three different locations in remote areas of the country.

Centralized installation at one substation will present an opportunity for flexible use of the equipment and multiple use of auxiliary installations required for the back-to-back stations. The total CAPEX for the back-to-back stations will be significantly lower if they are installed at one central location.

The following detailed measures are expected for development stage B:

(i) erection of back-to-back substation 500 kV at Pul e Chomri, including 500 kV switchgear and construction of 500 kV line from Sheberghan to Pul-e-Chomri with a length of about 280 km with operation of the entire link from TKM at design voltage 500 kV: The transfer capacity of the back-to-back converter station is scalable and should be chosen in the necessary size matched to the import capacity. Optimization results indicate the use of two 500 MW units.
(ii) expansion of Andkhoy substation with a second interbus transformer 220/110 kV with a capacity of 50 MVA and construction of a 220 kV double-circuit line from Andkhoy to Sheberghan with a length of about 70 km
(iii) expansion at Sheberghan with a second interbus transformer 220/110 kV with a capacity of 50 MVA, expansion of Mazar-e-Sharif 220kV substation and stringing of the second circuit of the line from Sheberghan to Mazar-e-Scharif.

With system configuration stage B, power import from Turkmenistan can be 1000 MW, depending on the size of the back-to-back converter station. This configuration is the starting point for a national grid of Afghanistan with all generation units of Afghanistan connected. There is enough transfer capacity available to wheel power from north to south as far as Kandahar.

Switching of lines from TAJ to Pul-e-Chomri to the bus section of the national grid of Afghanistan and operation of an isolated area as a static load without its own generation units in Tajikistan, wheeling of power from Turkmenistan to Tajikistan will be possible.

The estimated costs of development stage B are $535.8m in total.

T_01_B Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Andkhoy	220kV	1			0.9	$m
expansion substation Andkhoy	110kV	1			0.5	$m
transformer Andkhoy	220/110kV	1	50		1.0	$m
expansion substation Sheberghan	220kV	3			2.7	$m
expansion substation Sheberghan	110kV	1			0.5	$m
transformer Sheberghan	220/110kV	1	50		1.0	$m
expansion subst. Mazar-e-Sharif	220kV	1			0.9	$m
500MW HVDC back to back Pul-e-Chomry	500/500kV	2			380.0	$m
500kV line Sheberghan - Pul-e-Chomri	1x3x3xACSR400			280	106.4	$m
220kV line Andkhoy - Sheberghan	2x3x2xACSR300			70	29.8	$m
220kV line Sheberghan - Mazar-e-Sharif second circuit	2x3x2xACSR300			140	11.9	$m
Subtotal T_01_B					535.8	$m

Table 6.3.2-3: CAPEX details for Stage B of Turkmenistan - Afghanistan interconnector up to 2020

More than half of the CAPEX for development stage B will be required for the back-to-back station for two times 500 MW.

<u>Development Stage C up to 2025:</u>
Stage C will enable a second infeed from UZB or alternatively from TAJ to the national grid of Afghanistan.

Development Stage C comprises the following measures:

(i) Construction of a back-to-back substation 300 MW at Pul e Chomri, including 220 kV switchgear and switchgear expansion. The transfer capacity of the back-to-back converter station is selected according to the maximum import from Uzbekistan, which is limited to 300 MW.
(ii) Expansion of 220 kV switchgear at Pul-e-Chomri to connect the lines from Tajikistan to the substation. The design should allow connection alternatively to both sides of the new converter.

The additional converter will be used either for import from UZB or TAJ during spring and summer. During the winter season, it will be possible to switch the lines from TAJ to Pul-e-

Chomri to the bus section of the national grid of Afghanistan and to operate an isolated area as a static load without its own generation units in Tajikistan. This configuration will allow import from UZB and TKM and export to TAJ during the winter season.

CAPEX for this development stage is also driven by the necessity of back-to-back stations due to asynchronous operation of the systems.

The estimated costs for development Stage C are $101.7m in total.

T_01_C Measure	Type	No	[MVA]	[km]	Cost	
300MW HVDC back-to-back Pul-e-Chomry	220/220kV	1			99.0	m$
expansion substation Pul-e-Chomri	220kV	3			2.7	m$
Subtotal T_01_C					101.7	m$

Table 6.3.2-4: CAPEX details for Stage C of Turkmenistan - Afghanistan interconnector up to 2025

<u>Development Stage D up to 2032:</u>
With implementation of an additional back-to-back converter on the line from Tajikistan, all imports will be independently connected to the national grid of Afghanistan. An additional back-to-back converter on the TKM import line will increase the import capacity from TKM.

CAPEX for this development stage is also driven by the necessity of back-to-back stations due to asynchronous operation of the systems.

The expected expansions for Stage D will be:

(i) construction of back-to-back substation 300 MW at Pul e Chomri, including 220 kV switchgear.

The size of the additional converters can be chosen according to the available or required import capacities in future.

The estimated costs for development Stage D are $99m in total.

T_01_D Measure	Type	No	[MVA]	[km]	Cost	
300MW HVDC back-to-back Pul-e-Chomry	220/220kV	1			99.0	m$
Subtotal T_01_D					99.0	m$

Table 6.3.2-5: CAPEX details for Stage D of Turkmenistan - Afghanistan interconnector up to 2032

6.3.3 Additional Hindu Kush crossing

6.3.3.1 Study of constraints at Salang Pass

For the proposed 500kV HVDC transmission line from Tajikistan to Pakistan via Afghanistan, line routing has been investigated by SNC-Lavalin and described in their Final Feasibility Update Report Central Asia-South Asia Electricity Transmission and Trade (CASA-1000), dated February 2011.

Under the scope of this Power Sector Master Plan, Fichtner will study and analyze the constraints imposed by the Salang Pass, where space for additional transmission circuits is severely restricted. The optimum solution for the north-south connection will be identified, considering the possibility of adding new circuits in the Salang Pass or realizing alternatives like the Bamyan route which bypasses the Salang Pass.

Brief description of SNC line routing:
The line starts in Sangtuda in Tajikistan, crosses the border to Afghanistan near Shir Khan, runs south passing Kunduz, Mahajer, Baghlan and Pul-e-Chomri, and enters the mountain range of the Hindu Kush at Doshi. For this section of the line no difficulties are noted and the SNC design is considered to be suitable.

After Doshi, at angle point A25, the line makes a sharp turn and follows the highway and an existing 220 kV double-circuit line through the mountain range with its highest point at the Salang Pass at 4100 masl. In this zone, routing options are very limited as the right-of-way is already occupied by the 220 kV line. SNC Lavalin suggests relocating a section of this line or replacing it by underground cables to gain sufficient space for the proposed 500 kV HVDC line. Relocation costs are estimated by SNC Lavalin as US$28 million.

After the pass, on the south side, the line route heads towards Charikar and crosses a high altitude plateau up to Kabul, passing the capital city to the north near the international airport and joins the highway to Jalalabad at point A59. Finally the line continues to Jalalabad and Peshawar in Pakistan. From Charikar (A47) up to Kabul, the SNC line route is considered to be suitable except around A56 where it is very close to buildings and an industrial area.

Fichtner’s comments:
Fichtner carefully reviewed the Final Feasibility Report for CASA 1000, gathered additional information in Afghanistan and analyzed the situation for transmission line routing as follows:

The line section between A28 and A44 is where difficulties are expected and in particular where the line runs through narrow valleys and gorges.

The obstacles for running a 500 kV HVDC line through the Salang Pass are quite considerable and unconventional solutions are needed.

- The SNC proposal of relocating a section of the existing 220 kV OHL or using underground cables cannot be recommended as this will interrupt the power supply to

Kabul or create weak points on the line, in addition to the difficulties of digging cable trenches there and the high associated costs.

- The use of multi-circuit towers to combine the two lines in the same ROW cannot be recommended as the tower height and width will increase even more and the power supply to Kabul will be completely interrupted if a tower fails. In addition, the existing 220 kV line will have to be disconnected for a longer period, which is probably not acceptable.
- The main problem is to reduce the corridor width while avoiding steep mountainside slopes where the ground clearance under conductor swing conditions will force an increased tower height; moreover, due to critical leg and stub extensions in such zones, the space needed for foundation works will dramatically increase.
- Where not otherwise possible, the line will have to run outside the valley, which will increase construction costs and expose it to even more severe climatic conditions.
- Access from the main road to the tower sites will certainly involve heavy construction works and the use of cable transportation.
- There is little space to install the winch and drum sites for stringing a quad-conductor.
- Due to the unfavorable weight/wind span ratio due to the large differences in elevation, the number of tension towers will be very high and can be estimated as 60% of the total number of towers for this section.
- Special towers are needed in such mountainous terrain to cope with the topography: short towers with «negative body extensions», extended range towers for valley crossings, short tower members to facilitate transportation, leg protection against avalanches, etc.

Recommendations:
To sum up, Fichtner considers that the proposed line routing over the Salang Pass, even if technically possible, is associated with such difficulties and constraints that another more convenient and safer solution has to be investigated, even if the line route becomes longer.

In addition, routing over the Salang Pass would only be interesting if the proposed substation or converter station is located north or northeast of Kabul and if the line route continues to Jalalabad and the Pakistan border. Otherwise, if the concept as a whole is amended, then this routing should definitely be abandoned.

6.3.3.2 Alternative route

Because relocation or cabling of the existing 220 kV transmission line from Pul-e-Chomri to Kabul through the Salang Pass to accommodate the proposed 500 kV line as suggested by SNC Lavalin is considered to be not feasible, new line routing for the entire Salang Pass section, in which the difficulties and constraints are too severe, should be investigated.

In addition, new perspectives resulting from the present Master Plan should of course be incorporated, as these have a significant impact on the line route.

A new converter station will be constructed near Pul-e-Chomri, so the line from Pul-e-Chomri to Kabul will be HVAC and no longer HVDC. This will change the tower silhouette as the line will now have three conductors per circuit instead of one, resulting in longer cross arms or higher towers and larger footings, and will thus be even less suitable for the restricted corridor along the Salang Pass route.

The line route from the Tajikistan border to the vicinity of Pul-e-Chomri, as envisaged in the SNC Lavalin Feasibility Updated Report will remain as it is and has only to be adapted over the last few kilometers to the final location of the converter station.

In addition, as the new line will not be extended up to Peshawar in Pakistan, the routing north-east of Kabul towards Jalalabad is no longer a constraint. The line will now end at the Chimtala Substation on the western side of Kabul.

The planned connection between NEPS and SEPS (NEPS-Kandahar tactical tie-in) will necessitate the construction of a new substation south of Kabul in the future.

In view of the above, Fichtner undertook preliminary investigations to identify a more suitable line route adapted to the new situation.

Overviews showing the proposed line route for the alternative Bamyan route on satellite maps and topographic maps are given in **Annex 6.3.3-1** and **2.**

Key criteria for route selection

Key criteria applied for selection of the alternative route are:

- The line shall avoid protected or restricted areas.
- The line route shall follow existing roads – major or secondary – such that reasonable access for construction, inspection and maintenance is provided.
- The line route shall avoid villages, mountain slopes running parallel to it, erosion and rubbles zones and areas where severe ice and wind loads are expected.
- The line shall connect the future Pul-e-Chomri 500/220 kV Substation to the existing 220 kV substation in Kabul/Chimtala.
- The line shall be double-circuit AC with various tower type families adapted to installation contingencies due to terrain altitude.
- During the construction period, outages of existing lines shall be kept to a minimum and shall comply with power supply operation constraints.
- The line route and the tower design shall allow for future power supply development, as free space for new lines is limited due to difficult access and topographical conditions throughout the Hindu Kush.

Description of 500 kV HVAC line route proposal (termed the Bamyan Route)

The existing Pul-e-Chomri substation is located 2 km east of the A76 highway on a slightly sloped hill at 690 masl. The present substation plot is too small for all installations for the converter station, so some would have to be built outside the existing boundary wall. The site is prone to water erosion and there is no permanent access. The converter station could be built some 250 m to the east and linked to the new 500/220 kV substation within the boundary wall by an overhead connection crossing over the existing 220 kV lines.

The SNC routing should be modified starting at AP13 and rerouted over 17.5 km up to the converter station. Thus the total line length from the Tajikistan border to the converter station would amount to 150 km. This section of the line presents no particular difficulties and all tower locations are below 1000 masl.

From Pul-e-Chomri southwards, the alternative line routing as proposed by Fichtner would first run parallel to the existing 220 kV line to Kabul and then follow the valley and the highway down to the village of Doshi (former SNC AP24).

The line would then turn to the southwest following the road and the valley up to the crossing with the A77 highway leading to Bamyan near the village of Bariki.

Over the first 75 km, the altitude will remain between 690 and 1000 masl. The valley is tortuous, but access is good and space is sufficient for the line.

Between AP30 and AP50, the line rises to 2000 masl, the valley is narrower and some side roads will probably be needed to access all tower sites. After AP50, the line will continue rising to 3000 masl as it would first follow the A77 highway for a few kilometers and then continue south to reach a maximum altitude of 3500 m near Pay Kotal Pass. After Zarkharid, the altitude would drop to 2500 masl as the line route would follow the A77 highway again, this time eastwards, and reach the A1 road near Mami Khel, south of Kabul.

From this crossroad, the route would head north to finally reach the Chimtala substation at 1900 masl after 30 km while crossing some villages and agricultural land that could hardly be totally avoided. It should also be noted that the Chimtala substation is already surrounded by housing and that free corridors for future lines are very limited in the area.

On the whole, construction along the proposed line route would not be an easy task as the topographical and climatic conditions in the Hindu Kush are harsh, but definitely easier than over the Salang Pass, which rises to 4500 masl.

The total length of the proposed alternative route between the two substations is 316.3 km, compared to 198.4 km over the Salang Pass for the same connection which means an additional length of roughly 118 km.

Considering a unit price of US$0.38m the additional cost would be US$44.8m for a 500 kV HVAC line, minus the relocation costs in the Salang Pass area.

Alternative substation site for Kabul

Considering that Chimtala Substation is already surrounded by housing, this site is not ideal for the foreseen construction, as it is congested, too small, difficult to access, with insufficient corridor space and close to housing. Furthermore, for the future NEPS-SEPS connection a new substation will be needed south of Kabul. It would be advisable to plan a new 500/220 kV substation near Arghandi, which would combine the following advantages:

1. shorter 500 kV HVAC line (-30 km) and associated cost savings
2. new 220 kV line to the existing Chimtala 220 kV field (30 km) with less impact and costs than a 500 kV line
3. shorter future connection to Kandahar (-30km) for 500 or 220 kV lines
4. free space around the site for future lines to the east and south.

Considering the new substation Kabul South West (Arghandi) as landing point for the new Hindu Kush crossing the alternative Bamyan route will be about 88km longer than the route along the Salang Pass.

<u>Additional benefits of the alternative Bamyan route</u>

The alternative Bamyan route would pass the Afghan coal deposits in Samangan and Bamyan, and would cross the area of the Hajigak iron deposit further on.

Routing the line along this resource corridor would support power evacuation from the coal-fired power plants expected to be erected in this region in connection with the iron and copper mining projects. Furthermore, the line will ensure a power supply to the Hajigak iron mining project itself.

This multiple use of the transmission line has to be considered in the proposal for the line design of the additional connection of the Kabul region to the import point in north Afghanistan.

6.3.3.3 Conclusion and staged development of additional Hindu Kush crossing

The 220 kV double-circuit line currently crossing the Hindu Kush from north to south has been identified, already for the existing load conditions, as a bottleneck for power transfer from the sources in the north to Kabul.

To make use of the full 300 MW available from Turkmenistan as early as possible, to enable utilization of the gas from Sheberghan and to make use of the opportunity to import additional power up to a total of 1000 MW from Turkmenistan, wheeling of the power from northwest Afghanistan to other load centers is necessary.

Due to the expected required high transmission capacity and the limitation on transmission line corridors available for the crossing, it is advisable to use 500 kV lines within long-term planning. The recommendation is to use the Bamyan route for a new 500 kV line from Pul-e-Chomri to Arghandi in the south of Kabul.
The line will become an essential part of the backbone and it is recommended to use a double-circuit design for the towers with one circuit installed in the initial phase. The second circuit

will be installed in line with increasing transfer capacity caused by additional power sources in the north and along the Bamyan route.

Development Stage A up to 2015:
Due to the high priority given to this line, it is expected that project preparation works will start immediately, although the final commissioning date is expected to be early in the period from 2015 to 2020. Therefore, CAPEX for the first stage of the Hindu Kush crossing project is included in the Stage A development.

Network development for the additional Hindu Kush crossing project within Stage A will comprise the following:

(i) erection of a 500 kV substation at Pul-e-Chomri with two interbus transformers 500/220 kV each with a capacity of 300 MVA
(ii) erection of a 500 kV substation at Arghandi with two interbus transformers 500/220 kV each with a capacity of 300 MVA
(iii) construction of a 500 kV line from Pul-e-Chomri to Arghandi / Kabul South with a line length of about 296 km.

The expected CAPEX required for this development stage will amount to $238.2m. With regard to the double-circuit transmission line with only one circuit installed, 80% of the costs of the double-circuit line are considered. The remaining 20% of CAPEX will be necessary when stringing the second circuit.

T_02_A Measure	Type	No	[MVA]	[km]	Cost	
new substation Pul-e-Chomri	500kV	3			14.8	$m
expansion substation Pul-e-Chomri	220kV	2			1.8	$m
transformer Pul-e-Chomri	500/220kV	2	300		11.4	$m
new substation Arghandi	500kV	3			14.8	$m
expansion substation Arghandi	220kV	2			1.8	$m
transformer Arghandi	500/220kV	2	300		11.4	$m
500kV line Pul-e-Chomri - Arghandi first circuit	2x3x3xACSR400			296	182.2	$m
Subtotal T_02_A					238.2	$m

Table 6.3.3-1: CAPEX details for Stage A of Hindu Kush crossing up to 2015

Development Stage B up to 2020:
Network development for the additional Hindu Kush crossing considered in Stage A is likely to continue in Stage B. Additional CAPEX for development Stage B is not expected.

Development Stage C up to 2025:
Stage C development of the additional Hindu Kush crossing comprises:

(i) installation of an additional interbus transformer 500/220 kV at Pul-e-Chomri with a capacity of 300 MVA and

(ii) installation of an additional interbus transformer 500/220 kV at Arghandi with a capacity of 300 MVA

and will require a CAPEX of about $19.8m, as detailed in the table below.

T_02_C Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Pul-e-Chomri	500kV	1			3.3	m$
expansion substation Pul-e-Chomri	220kV	1			0.9	m$
transformer Pul-e-Chomri	500/220kV	1	300		5.7	m$
expansion substation Arghandi	500kV	1			3.3	m$
expansion substation Arghandi	220kV	1			0.9	m$
transformer Arghandi	500/220kV	1	300		5.7	m$
Subtotal T_02_C					19.8	m$

Table 6.3.3-2: CAPEX details for Stage C of Hindu Kush crossing up to 2025

<u>Development Stage D up to 2032:</u>
At the end of the planning horizon, the power flow at the additional Hindu Kush crossing may require the

(i) installation of the second circuit of the 500 kV line.

The required CAPEX is estimated at $52.1m. Stringing of the second circuit of the line is estimated at 40% of the double-circuit line.

The necessity of this development stage within the planning horizon is not clearly indicated.

T_02_D Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Pul-e-Chomri	500kV	1			3.3	$m
expansion substation Arghandi	500kV	1			3.3	$m
500kV line Pul-e-Chomri - Arghandi second circuit	2x3x3xACSR400			296	45.5	$m
Subtotal T_02_D					52.1	$m

Table 6.3.3-3: CAPEX details for Stage D of Hindu Kush crossing up to 2032

6.3.4 NEPS to SEPS interconnection

SEPS power supply is based on thermal generation with diesel sets in Kandahar and hydro generation at Kajaki Hydropower Plant. Major hydropower resources are identified in the northeast of Afghanistan. The potential for expansion of hydropower generation in SEPS is limited to the potential along the Helmand River and generation from imported diesel is not economically justifiable for long-term planning on a large scale. Thus linking SEPS to NEPS to transfer the power generated or imported in the north will be an option for the SEPS power supply.

The length of this line will be about 480 km and will mainly follow the road from Kabul to Kandahar. This line offers the opportunity for connecting the provinces to the national grid along its route.

Currently USAID is supporting the project of erecting such a transmission line on the 220 kV level. For its design, a single-circuit line on single-circuit towers or double-circuit towers with one circuit installed are under discussion for project implementation.

In the course of the network study for the Power Sector Master Plan, the suitability of the design and the requirements for any additional equipment to attain stable network conditions will be checked.

6.3.4.1 Conclusion and staged development of the NEPS to SEPS interconnector

The project for construction of an interconnector between the North East Power System and the South East Power System of Afghanistan is a major project driven by the international donor USAID. The project preparation works for a double-circuit line at the 220 kV level are ongoing and it is expected that a large part of the line will be commissioned in development Stage A. The line will connect the 220 kV substation at Arghandi and the 220 kV substation at Kandahar. Arghandi substation to the south of Kabul is expected to be included in the content of the Kabul transmission network development and, therefore, only the expansions required for the line feeders are included in the NEPS to SEPS interconnector project. Within SEPS, the new 220 kV substation at Kandahar together with the two interbus transformers 220/110 kV will be constructed for the interconnector project and, therefore, the substation and the transformers are included in the NEPS to SEPS interconnector project.

The substations along the NEPS to SEPS interconnector required for the power supply of the region passed by the line are considered within the network development within the provinces. Exact locations and naming convention for the substations are still under discussion and the proposed substation locations and names are only preliminary and will be subject of clarification during detail design phase for the different projects. Furthermore usage of 220/20 kV or 220/110/20 kV design within the substations will depend on the transmission and distribution requirements of the provinces and will be also subject of detailed planning within the provinces.

Development Stage A up to 2015:
Development Stage A for the NEPS to SEPS interconnector will comprise:

(i) expansion of Arghandi substation
(ii) erection of a new substation 220 kV at Kandahar with two interbus transformers 220/110 kV each with a capacity of 50 MVA
(iii) construction of the first circuit of the 220 kV line from Arghandi to Kandahar with a length of about 450 km.

The CAPEX for Stage A of the NEPS to SEPS interconnector is estimated at $191.3m. With regard to construction of the first circuit of the double-circuit line, CAPEX of 80% of the full double-circuit line is considered.

T_03_A						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Arghandi	220kV	1			0.9	$m
new substation Kandahar	220kV	3			6.5	$m
expansion substation Kandahar	110kV	2			1.1	$m
transformer Kandahar	220/110kV	2	50		2.1	$m
220kV line Arghandi - Kandahar first circuit	2x3x2xACSR400			450	180.7	$m
Subtotal T_03_A					191.3	$m

Table 6.3.4-1: CAPEX details for Stage A of NEPS to SEPS interconnector up to 2015

Development Stage B up to 2020:
It is not clear whether the interconnector can be commissioned over its full length by 2015. Finalization of the first stage is expected for Stage B. Further CAPEX in the period from 2015 to 2020 will be not required for the NEPS to SEPS interconnector.

Development Stage C up to 2025:
In the period from 2020 to 2025

(i) expansion of Arghandi and Kandahar substations with line feeders and stringing of the second circuit on the 220 kV line from Arghandi to Kandahar, length about 450 km

is expected and the CAPEX required for this Stage C will be about $47.0m. With regard to stringing of the second circuit of the double-circuit line, 20% of the CAPEX for the entire double-circuit line is considered in the cost estimate.

T_03_C						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Arghandi	220kV	1			0.9	$m
expansion substation Kandahar	220kV	1			0.9	$m
220kV line Arghandi - Kandahar second circuit	2x3x2xACSR400			450	45.2	$m
Subtotal T_03_C					47.0	$m

Table 6.3.4-2: CAPEX details for Stage C of NEPS to SEPS interconnector up to 2025

Development Stage D up to 2032:
Stage D will require no CAPEX for the NEPS to SEPS interconnector.

6.3.5 Connection to Pakistan

The connection to Pakistan will present an opportunity for power export to Pakistan once surplus power in Afghanistan or from the neighboring countries in the north is available and the new Hindu Kush crossing is in operation.
The connection to Pakistan should be of 500 kV design and the line will start from the new 500 kV substation at Arghandi, which will be part of the Hindu Kush crossing project. Therefore, the project can be considered for the period from 2015 to 2020 at the earliest. Focusing only on Afghan needs, the 500 kV connection from Arghandi to the east will be required in line with commissioning of the large Kunar A and Kunar B hydropower projects or in case that additional power supply is required in region Nangarhar. It was mentioned in late information from USAID that an additional load centre is expected in Nangarhar and power system development is expected in that region. 500 kV connection from Arghandi to Jalalabad will provide secure power supply for that region.

Development Stage A up to 2015:
During the first stage, the Hindu Kush crossing will not be commissioned and, therefore, construction of the connection to Pakistan will not be possible in Stage A.

Development Stage B up to 2020:
If export to Pakistan is given high priority during Stage B,

(i) expansion of Arghandi substation and construction of the 500 kV transmission line from Arghandi to the border to Pakistan via Jalalabad with a line length of about 210 km

will require a CAPEX of about $83.1m.

T_04_B Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Arghandi	500kV	1			3.3	m$
500kV line Arghandi - Jalalabad	1x3x3xACSR400			140	53.2	m$
500kV line Jalalabad - Pakistan	1x3x3xACSR400			70	26.6	m$
Subtotal T_04_B					83.1	m$

Table 6.3.5-1: CAPEX details for Stage B of the connection to Pakistan up to 2020

If the focus is on Afghan needs, this CAPEX could be shifted to the later Stage D.

Development Stage C up to 2025:
Stage C will require no CAPEX for the connection to Pakistan.

Development Stage D up to 2032:
Stage D will require the following installations:

(i) erection of a new substation 500 kV at Jalalabad with three interbus transformers 500/220 kV each with a capacity of 100 MVA and loop-in to the line to Pakistan.

This will require a CAPEX of $29.7m.

T_04_D						
Measure	Type	No	[MVA]	[km]	Cost	
new substation Jalalabad	500kV	5			21.3	m$
expansion substation Jalalabad	220kV	3			2.7	m$
interbus transformer Jalalabad	500/220kV	3	100		5.7	m$
Subtotal T_04_D					29.7	m$

Table 6.3.5-2: CAPEX details for Stage D of the connection to Pakistan up to 2032

6.3.6 Herat Interconnector

Herat province is the region with the second-highest power consumption in Afghanistan. Currently, power supply is by import from Iran and Turkmenistan. Under the master plan, connection of this province is by means of the construction of a double-circuit line at 220 kV from the northern province of Faryab crossing the province of Badghis. The Herat interconnection will also be used to connect substations along the line route in Faryab and Badghis provinces and it is expected that the first parts of the line will be constructed in the early stages. The total length of the Herat interconnector from Andkhoy to Noor Jahad is estimated at about 405 km.

Development Stage A up to 2015:
For the period up to 2015, it is expected that first stage of the Turkmenistan - Afghanistan interconnector will be implemented and that the 220 kV level with a strong connection to Turkmenistan for import will be available.
The following installations for the Herat interconnector are required in Stage A:

(i) Expansion of Andkhoy substation with one line feeder and construction of the first part of the transmission line from Andkhoy to Noor Jahad up to Maimana with a line length of about 140 km. The line should be designed as a double-circuit line with one circuit installed.

The estimated costs for development Stage A are about $48.6m. The substation at Maimana will be included in network development for Faryab province. With regard to the double-circuit line with one circuit installed, we assume 80% of the CAPEX for the double-circuit line.

T_05_A						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Andkhoy	220kV	1			0.9	$m
220kV line Andkhoy - Noor Jahad first part, first circuit	2x3x2xACSR300			140	47.7	$m
Subtotal T_05_A					48.6	$m

Table 6.3.6-1: CAPEX details for Stage A of the Herat interconnector up to 2015

Development Stage B up to 2020:
For the period 2015 to 2020, extension of the interconnection line as far as Abdulhkar in the province of Badghis is expected. Therefore, the second part of the transmission line from Andkhoy to Noor Jahad will require:

(i) construction of a double-circuit line with one circuit installed from Maimana to Abdulkhar with a length of about 155 km.

Stage B CAPEX will be about $52.8m. The substations at Maimana, Almar and Qaisar will be included in network development for Faryab province and the substation at Abdulhkar will be included in network development for Badghis province. With regard to the double-circuit line with one circuit installed, we assume 80% of the CAPEX for the double-circuit line.

T_05_B						
Measure	Type	No	[MVA]	[km]	Cost	
220kV line Andkhoy - Noor Jahad second part, first circuit	2x3x2xACSR300			155	52.8	$m
Subtotal T_05_B					52.8	$m

Table 6.3.6-2: CAPEX details for stage B of the Herat interconnector up to 2020

Development stage C up to 2025:
Within stage C completion of the connection to Herat by

(i) construction of the third part of the 220 kV line from Abdulkhar to Noor Jahad with a length of about 110 km and expansion of the substation Noor Jahad.

This part of the connection line shall also be designed as double-circuit line with on circuit installed.
Construction of the line portion from Noor Jahad to Qala-e-Naw may be possible also in an early stage, if there is enough power available in Herat.

CAPEX for Stage C is estimated at about $38.4m. The substations Abdulhkar and Qala-e Naw will be included in network development considered for Badghis province. For the double-circuit line with one circuit installed we are assuming 80% of the CAPEX of the double-circuit line.

T_05_C						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Noor Jahad	220kV	1			0.9	$m
220kV line Andkhoy - Noor Jahad third part, first circuit	2x3x2xACSR300			110	37.5	$m
Subtotal T_05_C					38.4	$m

Table 6.3.6-3: CAPEX details for Stage C of the Herat interconnector up to 2025

<u>Development Stage D up to 2032:</u>
The interconnector will be finalized in Stage D by:

(i) installation of the second circuit along all three parts of the interconnection line with a total length of 405 km.

The estimated CAPEX will be about $36.3m. Stringing of the second circuit is estimated at 20% of the CAPEX for the complete double-circuit line.

T_05_D						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Andkhoy	220kV	1			0.9	$m
expansion substation Noor Jahad	220kV	1			0.9	$m
220kV line Andkhoy - Noor Jahad second circuit	2x3x2xACSR300			405	34.5	$m
Subtotal T_05_D					36.3	$m

Table 6.3.6-4: CAPEX details for Stage D of the Herat interconnector up to 2032

6.3.7 CASA 1000 Project

World Bank is strongly promoting the development of a HVDC connection between Central Asia and South Asia crossing the Hindu Kush to transport surplus power during spring and summer from the hydro dominated power systems of Kirgizstan and Tajikistan to Pakistan. To allow Afghanistan to participate on that investment, installation of a terminal near Kabul at Chimtala substation is foreseen with a capacity of 300 MW.
Routing of the HVDC line is proposed from Tajikistan, passing by Pul-e-Chomri and using the Salang Pass corridor up to Kabul.
According to the Project Feasibility Study Update February 2011 time period for implementation is estimated with 58 to 70 month from award of consultancy contract covering investment of $873m for the whole interconnection line and the multi terminal converter stations.
The investment has to be placed during development Stage A and Stage B and commissioning is expected earliest in 2018/2019.

6.3.8 Conclusion

The proposed major network projects new Turkmenistan to Afghanistan interconnector and additional Hindu Kush crossing in the staged development of the northwest part of Afghanistan will allow use of the generation capacity in Turkmenistan for export to Afghanistan once the capacity is available. For wheeling the power to the south, the Hindu Kush crossing is expected to be available early in development Stage B.

The concept provides maximum flexibility and ensures that CAPEX will fit into future development. It will be possible to adapt the further stages to possible developments without wasting CAPEX that has already been undertaken.

Construction of the NEPS to SEPS interconnector at the 220 kV level will be feasible and will ensure a secure power supply to Kandahar as well as making it possible to connect the provinces along the line route to the national grid.

With regard to the connection to Pakistan, it should be pointed out that extension of the 500 kV network as far as the border with Pakistan in the early stage will only be justified in case of significant export to Pakistan. For Afghan needs, the 500 kV line from Arghandi to Jalalabad is required in line with construction and commissioning of the large Kunar A and Kunar B hydropower plants, which are expected for development Stage D.

The Herat interconnector will allow a power supply from the national grid to the region with the second-highest power consumption. Furthermore, the line will support development of the transmission network in the provinces along the route of the Herat interconnector which will be realized in stages.

The total CAPEX for the projects over the planning horizon is estimated at about $1,726.8m including reactive power compensation equipment.
A summary of the CAPEX for the major transmission projects required for the project as a whole and a breakdown into development stages is given in the following Table 6.3.8-1.

Major transmission project		Investment [m$]				
		Subtotal by project	Stage A	Stage B	Stage C	Stage D
T_01	TKM-AFG interconnector	843.0	106.5	535.8	101.7	99.0
T_02	Hindu Kush crossing	310.1	238.2		19.8	52.1
T_03	NEPS to SEPS interconnector	238.2	191.3		47.0	
T_04	Connection to Pakistan	112.8		83.1		29.7
T_05	Herat interconnector	176.1	48.6	52.8	38.4	36.3
	Reactive power compensation	46.5	10.4	5.2	6.0	24.9
	Total	1726.8	595.0	676.9	212.9	242.0
T_06	CASA-1000	873.0	228.0	645.0		

Table 6.3.8-1: Summary of CAPEX for major transmission projects

To summarize, the CAPEX for each project in the development stages shows $595m for development Stage A, which is driven by the immediate need for network reinforcement to overcome the current shortages of transfer capacity for major interconnections and about $676.9m for development Stage B, which includes a large part of the $380m for the back-to-back stations at Pul-e-Chomri. The total CAPEX for the major transmission projects includes a total of $578m for the back-to-back stations.

The investment for CASA-1000 will be in stage A about half and in stage B in the same range as the total of the other major transmission projects required for development of Afghanistan transmission network. This investment will be covered by World Bank for Afghanistan as well as for the involved neighboring countries.

6.4 Standardization

New equipment has to be designed according to IEC or equivalent standards. In general, however local standards also have to be considered.

500 kV substations are not yet installed in Afghanistan but in the Central Asia region the 500 kV switchyards are build in 1½ circuit breaker configuration.
For 220 kV switchyards a double busbar was build for major substations and single busbar scheme with longitudinal coupler at smaller substations. These configurations provide sufficient flexibility and redundancy to cope with disturbances and allow maintenance.

The substations are outdoor switchyards using air insulated technology
The Consultant recommends continuing with the use of this technology for the power system expansion, as long as there is enough space for erection of the substations or for substation expansions.

The capacity of the interbus transformer within the substations will be selected to cover the load which is allocated to the substation within the planning horizon. In general, development will start with one installed transformer but with sufficient spare space in the substation for a second transformer of the same size to be installed at a later stage to improve security of supply at substation level. For the interbus transformer, standard types shall be used.

In the latest investments in the transmission system, substations stepping down from 220 kV to 20 kV level were used. This is to be recommended in regions where the population is concentrated in a certain area and a further spread into rural areas is not expected. For regions with dispersed settlements, a subtransmission level of 110 kV will be necessary for transmission of the power from central in-feed points in the regions.

For the transmission lines 500 kV level is currently not used within Afghanistan. Within the neighboring systems, especially in Turkmenistan, the 500 kV lines are designed as single circuit using triple bundle conductor ACSR300 or ACSR400.

For the 220 kV level, the lines are designed as single-circuit or double-circuit lines either with single conductors ACSR 300 (1x3x1xACSR300, 2x3x1xACSR300) or with double-bundle conductors ACSR 300 (1x3x2xACSR300, 2x3x2xACSR300).

On the 110 kV level, the main design currently used is the single-circuit single-conductor line with ACSR 120, ACSR 150 or ACSR 185 conductors.

We are recommending using standard design for the transmission lines for the further development within Afghanistan with the following configuration.

500 kV single circuit	1x3x3xACSR400
500 kV double circuit	2x3x3xACSR400
220 kV single circuit	1x3x1xACSR400
220 kV double circuit	2x3x1xACSR400
110 kV single circuit	1x3x1xACSR185

7. Synchronous operation mode for Afghan power system

In principle, synchronous network operation with neighboring networks would to a certain degree have benefits for all involved.

Afghanistan is surrounded by four electrical systems operating asynchronously but feeding parts of the Afghanistan network, these being:

- Turkmenistan network and Iran network (operating synchronously)
- Uzbekistan network operating synchronously with CAPS
- Tajikistan network operating isolated from CAPS
- Pakistan network.

Due to the asynchronous operation of the surrounding networks, connection of these along with the Afghan network is not possible. Even local generation in Afghanistan is currently operating without connection to a neighboring network.

The procedure required for synchronous operation of Afghan generation units with a neighboring system was described in a presentation at the first meeting in Stuttgart, based on the example of synchronization with CAPS (see **Annex 7-1**).

A summary of measures for synchronous operation of the Afghanistan power system with CAPS is given in **Annex 7-2**.

The fact that currently a major portion of the load of Afghanistan is fed from different import sources and the exporters are keen to wheel power through Afghanistan to Pakistan has to be considered for network development in Afghanistan.

8. Transmission Expansion

Transmission expansion must cope with the expansion of generation and must connect the demand centers with the generation sources, either local generation or import.

The goal of the master plan is to maximize the coverage of Afghan electricity demand, supplying, in particular, the largest Afghan settlement areas in Herat, Kandahar, Kabul, Kunduz and Mazar-e-Sharif.

The side-effect of establishing a connection between the Central Asian republics and Pakistan to enable energy transfer from the Central Asian republics to Pakistan is discussed as an additional benefit for the construction of a national grid of Afghanistan.

As the time constraints in terms of planning and construction are still unknown, it was decided to make a distinction between the short-, medium- and long-term outlook within the timeframe of the master plan rather than in precise terms of years.

8.1 Transmission and Distribution Expansion to Cover Afghan Needs

To achieve the goal of maximizing the coverage of Afghan demand, development of the transmission network in line with the current operation mode of the Afghan grid, with further development of islanded areas supplied by different, asynchronously operating sources, was identified as one possible concept.

The establishment of an integrated transmission network in Afghanistan for maximum utilization of local generation with the goal of independent power supply is the preferred concept, which is currently promoted by MEW and DABS. However, import from the neighboring countries will also be an additional source of power supply for Afghanistan (for some regions).

Because the operation philosophy for the neighboring power systems might change in time, a variable, staged development has been considered.

In the *short term,* an increase of import line capacity to the currently isolated grids is of greatest importance. Additionally, the number of on-grid consumers should be increased as the import and generation capacity is expanded.

In the *medium term,* an HVDC back-to-back station at Pul-e-Chomri is supplied from the Turkmenistan power system. In this way, while constructing further converter stations, the system operator can choose between all the offered 500 kV and 220 kV imports. The generation capacity in the Kabul area is synchronized with the existing Afghan power system at the earlier NEPS. A new transmission line between Pul-e-Chomri and Argandi, south of Kabul, at 500 kV will eliminate the power transfer bottleneck to Kabul. Parts of the existing NEPS are still connected to neighboring power systems if the supply capacity of the Afghan power grid is insufficient. The NEPS to SEPS interconnector will secure the power supply to southern Afghanistan.

In the *long term*, more foreign power systems will feed in to the back-to-back hub at Pul-e-Chomri substation. A 500 kV transmission line at the Afghanistan-Pakistan border will be in place, transferring power from Central Asia to Pakistan and India. From Pul-e-Chomri, the Afghan power system is fed at the 500 kV and 220 kV levels. It is operated synchronously from a single network control center.

Up to now several measures were taken for improvement of the distribution system and connection rate increased significantly. Anyhow it is necessary to keep the momentum and to increase the efforts to expand the distribution system to reach the goal of high connection rate within Afghanistan.

8.2 Transmission Expansion Planning by Provinces

The following discusses at province level the network expansion planning required for improving the power supply to the provinces and for meeting future expected demand growth.

Total CAPEX on the transmission system over the planning horizon for all provinces of Afghanistan is estimated at about $1,056m.
With regard to allocation of CAPEX to the development stages within the planning horizon, it is expected that about $317m will be required in Stage A up to 2015 and about $430m in Stage B between 2015 and 2020.

To give an overview of the required CAPEX on improvement and expansion of the transmission networks in the provinces, the summary presented in Table 8.2-1 has been established and, for each province, the total required CAPEX and its allocation to development stages have been given.

Starting from the existing system, the possible expansions are discussed and justification for the selected alternative is given in the following sections for each province. Annexes present network development in the form of single line diagrams for the provinces. The annexes are numbered according to the number of the province and the expansion stage. For example, development in Kabul province, which is alphabetically the 14th province, is presented in the following annexes:

Annex 8.2.14-1 SLD of the existing Kabul network
Annex 8.2.14-2 SLD of the Kabul network including Stage A development
Annex 8.2.14-3 SLD of the Kabul network including Stage B development
Annex 8.2.14-4 SLD of the Kabul network including Stage C development
Annex 8.2.14-5 SLD of the Kabul network including Stage D development

For provinces without an existing transmission network or for development stages without implementation of additional measures, the single line diagrams are not included.

Network expansion for supply within the Provinces		Investment [m$]				
		Subtotal by Province	Stage A	Stage B	Stage C	Stage D
P_01	Province Badakhshan	59.7	56.1		3.7	
P_02	Province Badghis	22.9		11.4	7.7	3.9
P_03	Province Baghlan	23.8	14.6	2.5	6.8	
P_04	Province Balkh	21.2	19.3	1.9		
P_05	Province Bamyan	41.5		41.5		
P_06	Province Daykundi	24.2				24.2
P_05	Province Farah	0.0				
P_08	Province Faryab	38.3	9.0	28.6		0.7
P_09	Province Ghazni	38.8		31.5	1.2	6.0
P_10	Province Ghor	63.2		53.2		10.0
P_11	Province Helmand	18.7	8.4	1.7	8.6	
P_12	Province Herat	77.8	18.3	15.3	28.8	15.3
P_13	Province Jowzjan	12.1	11.0	1.1		
P_14	Province Kabul	135.3	60.3	27.0	39.4	8.6
P_15	Province Kandahar	14.2	4.9	1.6	3.3	4.4
P_16	Province Kapisa	25.9		23.7	2.2	
P_17	Province Khost	19.8		18.1	0.9	0.9
P_18	Province Kunar	16.1		14.4	0.9	0.9
P_19	Province Kunduz	40.9	25.6	8.5	6.8	
P_20	Province Laghman	1.7			0.9	0.9
P_21	Province Logar	19.1		17.6		1.6
P_22	Province Nangarhar	45.2		1.7	35.1	8.3
P_23	Province Nimruz	34.9			34.9	
P_24	Province Nuristan	0.0				
P_25	Province Paktia	18.2		17.0		1.2
P_26	Province Paktika	19.7		18.2		1.5
P_27	Province Panjshir	12.8		10.9	0.6	1.2
P_28	Province Parwan	18.1	8.5	7.2	2.5	
P_29	Province Samangan	9.5	7.6	0.7	1.2	
P_30	Province Sar-e Pol	33.3	10.6	21.3		1.4
P_31	Province Takhar	67.7	30.0	17.9	18.9	0.9
P_32	Province Uruzgan	34.9		26.1	8.8	
P_33	Province Wardak	15.9	6.1	7.7	0.9	1.2
P_34	Province Zabul	14.4		11.5	0.9	2.0
	Total	1040.1	290.1	439.8	215.1	95.0

Table 8.2-1: Summary of CAPEX for major transmission projects

8.2.1 Badakhshan

8.2.1.1 Existing system

Badakhshan province is located in the northeast of Afghanistan and borders on Tajikistan, China and Pakistan. Currently, the province has no power supply from the national grid. Small hydropower plants supply isolated areas and the connection rate was reported as about 5% in 2011.

8.2.1.2 Network expansion

Peak demand in Badakhshan province will increase to a predicted value of 76.4 MW, assuming a connection rate of 70% in 2032. The demand forecast for Badakhshan province is given in Table 8.2.1-1.

	Load and load forecast for Badakhshan						
Year	2010	2011	2012	2015	2020	2025	2032
Population [Thousand]	874.8	889.7					
No of Households [Thousand]	89.7	91.3	93.1	98.8	109.1	120.1	135.7
Connection rate [%]	4.0	5.2	10.2	25.1	50.0	58.3	70.0
Gross Electricity Demand [GWh]	2.4	3.4	8.5	36.4	128.5	215.0	401.5
Net Electricity Demand [GWh]	1.7	2.4	5.9	25.9	95.4	164.0	312.9
Peak Demand [MW]	0.5	0.7	1.8	7.6	26.7	44.6	76.4

Table 8.2.1-1: Load and load forecast for Badakhshan

The load centers in the province are expected to be at Faizabad and Kishem. The substation locations given in the following tables are tentatively taken from the map.

Further load centers for Badakhshan	Latitude N	Longitude E	
Faizabad	37° 7'15"	70°34'1"	*
Kishem	36°49'25"	70° 5'5"	*

* Substation coordinates estimated from map

Table 8.2.1-2: Further load centers for Badakhshan

Currently there are ongoing projects for construction of small hydro power plants near Kishem and Faizabad for local power supply within that region. These projects are promoted by KfW and it is recommended to continue to ensure power supply for that region.

Additional power supply to the load centers can be achieved by construction of a 220 kV line from the new substation at Taluqan. The line will be routed from Taluqan via Kishem and the proposed hydropower plant at Kukcha to Faizabad.

In view of the fact that the hydropower plant at Kukcha with a capacity of 445 MW is located along this line, the voltage level of 220 kV is justified. Power export from the new HPP at Kukcha must be considered for the line design. Therefore, construction of double-circuit towers with one circuit installed is recommended for the first phase of network development. Upon commissioning of Kukcha HPP, the second circuit must be installed.

To meet the expected demand in the load centers, the following stepwise development of transformer capacity is proposed.

	Existing and further transformer capacity [MVA] Badakhshan						
		2011	2012	2015	2020	2025	2032
Faizabad	1 x 16			16.0	16.0	16.0	16.0
Faizabad	2 x 16					32.0	32.0
Kishem	1 x 16			16.0	16.0	16.0	16.0
Kishem	1 x 16					16.0	16.0
Total		0	0	32	32	80	80

Table 8.2.1-3: Existing and further transformer capacity [MVA] for Badakhshan

Development of the loading of the transformer for the different development stages is given in Table 8.2.1-4.

	Existing and further load at substation level [MW] for Badakhshan						
		2011	2012	2015	2020	2025	2032
Faizabad				3.8	13.3	8.9	15.3
Faizabad						17.9	30.6
Kishem				3.8	13.3	8.9	15.3
Kishem						8.9	15.3
Total		0.0	0.0	7.6	26.7	44.6	76.4

Table 8.2.1-4: Existing and further load at substation level [MW] for Badakhshan

8.2.1.3 Overview

With regard to network development in Badakhshan province (P_01), the following stages were identified with an estimated total CAPEX of about $59.7m.

Network integration of the hydropower plant at Kukcha expected earliest in the period up to 2032 will require a CAPEX of about $70m.
The following expansion plan is justified for the case of considering the Kukcha HPP. Otherwise the connection could be realized on lower voltage level or the power supply could be based on local generation from the new small HPP in Kishem and Faizabad.

<u>Stage A up to 2015:</u>
For network development in Stage A, the following is proposed:

(i) erection of new substation 220/20 kV at Kishem with one transformer with a capacity of 16 MVA and construction of 220 kV line Taluqan to Kishem with a length of about 65 km

(ii) erection of new substation 220/20 kV at Faizabad with one transformer with a capacity of 16 MVA and construction of 220 kV line Kishem to Faizabad with a length of about 85 km.

Network development up to 2015 is given as single-line diagram in **Annex 8.2.1-2** and the expected CAPEX for Stage A is about $56m, as given below.

P_01_A Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Taluqan	220kV	1			0.9	m$
new substation Kishem	220kV	3			6.5	m$
transformer Kishem	220/20kV	1	16		0.3	m$
new substation Faizabad	220kV	2			6.0	m$
transformer Faizabad	220/20kV	1	16		0.3	m$
220kV line Taluqan - Kishem	1x3x2xACSR300			65	18.2	m$
220kV line Kishem-Faizabad	1x3x2xACSR300			85	23.8	m$
Subtotal P_01_A					56.1	m$

Table 8.2.1-5: CAPEX on power system in Badakhshan up to 2015

Stage B up to 2020:

Between 2015 and 2020, no additional CAPEX is required for the transmission system in the province of Badakhshan.

Stage C up to 2025:

Due to increased demand, additional transformer capacity must be installed in Badakhshan province. Details of the growth of population and the economy in the province are not known, especially for the later time horizon. Therefore, we assumed that one additional transformer in Kishem and two additional transformers in Faizabad will be necessary from 2025 onwards. Additional CAPEX for Stage C will be about $3.7m, as shown in Table 8.2.1-6. The network configuration for Badakhshan, including Stage C, is given in the single-line diagram in **Annex 8.2.1-4**.

P_01_C Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Kishem	220kV	1			0.9	m$
transformer Kishem	220/20kV	1	16		0.3	m$
expansion substation Faizabad	220kV	2			1.8	m$
transformer Kishem	220/20kV	2	16		0.6	m$
Subtotal P_01_C					3.7	m$

Table 8.2.1-6: Additional CAPEX for power system in Badakhshan up to 2025

Stage D up to 2032:

For stage D, no additional CAPEX will be required for the transmission network to meet demand growth in the province of Badakhshan.

In addition to network development to meet demand growth in the region, measures will be required for network integration of the hydropower plant at Kukcha. Commissioning of

Kukcha HPP is expected earliest during Stage D. The power plant will be looped into the line from Kishem to Faizabad about 43 km from Kishem. For secure power evacuation, a second circuit from Kukcha HPP to the network will be required and, therefore, the line from Kunduz 2 substation to Kukcha substation and loop-in of the second circuit of the line from Sangtuda to Pul-e-Chomri at Kunduz 2 substation is recommended. The estimated costs of network integration of Kukcha HPP are about $70m and include the step-up transformer to the transmission voltage level of 220 kV. Details are given in the table below.

G_07_D	Additional CAPEX up to 2032					
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Kunduz 2	220kV	3			2.7	m$
new substation Kukcha	220kV	6			7.8	m$
transformer Kukcha	220/20kV	3	180		11.1	m$
220kV line Kunduz 2 - Kukcha	1x3x2xACSR300			174	48.7	m$
Subtotal G_07_D					70.3	m$

Table 8.2.1-7: CAPEX on network integration of Kukcha HPP up to 2032

Network development for the transmission system, including Kukcha network integration, for Badakhshan province up to 2032 is given in **Annex 8.2.1-5**.

8.2.2 Badghis

8.2.2.1 Existing system

Badghis province in the west of Afghanistan on the border to Turkmenistan is currently not connected to the national grid of Afghanistan. There are existing power supply systems in the northern province of Faryab and in the southern province of Herat.

8.2.2.2 Network expansion

According to the load forecast, peak load will increase to about 40 MW in 2032 and the connection rate will reach a level of 70%

	Load and load forecast for Badgis						
Year	**2010**	**2011**	**2012**	**2015**	**2020**	**2025**	**2032**
Population [thousand]	456.4	464.1					
No of households [thousand]	46.5	47.2	48.1	51.1	56.4	62.1	70.1
Connection rate [%]	2.4	4.4	9.5	24.7	50.0	58.3	70.0
Gross electricity demand [GWh]	0.5	0.5	2.1	13.3	66.4	111.2	207.5
Net electricity demand [GWh]	0.3	0.3	1.4	9.4	49.3	84.8	161.8
Peak demand [MW]	0.1	0.1	0.4	2.8	13.8	23.1	39.5

Table 8.2.2-1: Load and load forecast for Badghis

Expansion of the national grid, particularly connection between Faryab and Herat by a transmission line, will present an opportunity to supply the load centers in Badghis. A major load center is expected to be Qala-e Naw, as the capital of the province, and along the River Darya-ye Murghab. Tentative locations of the new substations are given in the following table.

Further load centers for Badgis	Latitude N	Longitude E	
Qala-e Naw	34°59'24"	63°7'12"	*
Abdulkhar	35°17'20"	63°28'10"	*

* Substation coordinates estimated from map

Table 8.2.2-2: Further load centers for Badghis

The new connection line from the new substation at Qaisar to the substation at Noor Jahad in Herat will be routed along the load center in Badghis. This interconnection line is expected for 2025, although the first part for connection of the load center in Badghis may be possible in 2020.

The proposed transformer capacity at the new substations and the expected loading are given in the following tables.

		Existing and further transformer capacity [MVA] Badgis					
		2011	2012	2015	2020	2025	2032
Qala-e Naw	1 x 16					16.0	16.0
Qala-e Naw	1 x 16						16.0
Abdulkhar	1 x 16				16.0	16.0	16.0
Abdulkhar	1 x 16						16.0
Total		0	0	0	16.0	32.0	64.0

Table 8.2.2-3: Existing and further transformer capacity [MVA] for Badghis

		Existing and further load at substation level [MW] for Badgis					
		2011	2012	2015	2020	2025	2032
Qala-e Naw						11.5	9.9
Qala-e Naw							9.9
Abdulkhar					13.8	11.5	9.9
Abdulkhar							9.9
Total		0.0	0.0	0.0	13.8	23.1	39.5

Table 8.2.2-4: Existing and further load at substation level [MW] for Badghis

8.2.2.3 Overview

Transmission network development in Badghis province will start with construction of the Andkhoy - Herat interconnector, which is treated as a major transmission project in section 7.3.The interconnector will cover the expansion of the substations at Andkhoy and Noor Jabad as well as the transmission line itself. The substations along the line required to supply the areas along the route were included in the network development of the provinces.

The CAPEX required for network development in Badghis will be about $22.9m for staged development over the planning horizon.

Stage A up to 2015:
For the first stage, the interconnector to Herat will not be erected and, therefore, no CAPEX will be possible.

Stage B up to 2020:
Up to 2020, the first part of the Herat interconnector from Andkhoy south to the region of Abdulkhar is expected and the following measures are proposed for Stage B:

(i) erection of substation 220/110/20 kV at Abdulkhar with interbus transformer 220/110 kV with a capacity of 16 MVA and transformer 110/20kV with a capacity of 16 MVA.

With regard to the substation, the equipment for looping in and out of both circuits of the Herat interconnector is assumed to be installed in Stage B and the CAPEX is estimated at $11.4m. See **Annex 8.2.2-3** for the single-line diagram of the transmission network.

P_02_B						
Measure	Type	No	[MVA]	[km]	Cost	
new substation Abdulkhar	220kV	5			7.4	m$
new substation Abdulkhar	110kV	2			3.3	m$
transformer Abdulkhar	220/110kV	1	16		0.3	m$
transformer Abdulkhar	110/20kV	1	16		0.3	m$
Subtotal P_02_B					11.4	m$

Table 8.2.2-5: Additional CAPEX for power system in Badghis up to 2020

<u>Stage C up to 2025:</u>
In Stage C, the connection to Herat will be completed and it will be possible to connect the

(i) new substation 220/20 kV at Qala-e Naw with a transformer capacity of 16 MVA to the interconnection line.

CAPEX for this expansion is estimated at $7.7m and the single-line diagram for the transmission network is given in **Annex 8.2.2-4**.

P_02_C						
Measure	Type	No	[MVA]	[km]	Cost	
new substation Qala-e Naw	220kV	5			7.4	m$
transformer Qala-e Naw	220/20kV	1	16		0.3	m$
Subtotal P_02_C					7.7	m$

Table 8.2.2-6: Additional CAPEX for power system in Badghis up to 2025

<u>Stage D up to2032:</u>
To meet load growth up to 2032, the following will be required:

(i) installation of an additional interbus transformer 220/110 kV of capacity 16 MVA and transformer 110/20 kV of capacity 16 MVA at Abdulkhar
(ii) installation of additional transformer 220/20 kV of capacity 16 MVA at Qala-e Naw

Estimated CAPEX for Stage D will be about $3.9m.

P_02_D						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Abdulkhar	220kV	1			0.9	m$
expansion substation Abdulkhar	110kV	2			1.1	m$
transformer Abdulkhar	220/110kV	1	16		0.3	m$
transformer Abdulkhar	110/20kV	1	16		0.3	m$
expansion subst. Qala-e Naw	220kV	1			0.9	m$
transformer Qala-e Naw	220/20kV	1	16		0.3	m$
Subtotal P_02_D					3.9	m$

Table 8.2.2-7:Additional CAPEX for power system in Badghis up to 2032

Furthermore, installation of the second circuit of the Herat interconnector is proposed up to 2032. The resulting single-line diagram is given in **Annex 8.2.2-5**.

8.2.3 Baghlan

8.2.3.1 Existing system

Baghlan province is located north of the Hindu Kush and is crossed by the double-circuit 220 kV line from Naibabad to Chimtala via the substation at Pul-e-Chomri, which is currently the bulk supply point for Baghlan province. The connection rate was reported as 16% in 2011. In addition, the double-circuit line from Tajikistan is routed to Pul-e-Chomri.

Existing load centers Baghlan	Latitude N	Longitude E	
Pul-e-Chomri	35°58'26.08"	68°42'52.10"	*

* Substation coordinates given by DABS (DBS_026)

Table 8.2.3-1: Existing load centers for Baghlan

The single-line diagram for the existing transmission system in Baghlan province is given in **Annex 8.2.3-1**.

8.2.3.2 Network expansion

Baghlan, as the capital of the province, is a further load center in addition to Pul-e-Chomri. Furthermore, the valley to the Salang Pass with Khenjan and the valley from Doshi to the west are populated areas and we expect that power supply will be necessary for those areas. The preliminary coordinates of the new substations taken from maps are given in Table 8.2.3-3. According to the demand forecast, the expected peak load in Baghlan province is about 83 MW, as shown in the table below.

	Load and load forecast for Baghlan						
Year	**2010**	**2011**	**2012**	**2015**	**2020**	**2025**	**2032**
Population [Thousand]	833.3	848.5					
No of Households [Thousand]	94.3	96.2	98.1	104.1	115.0	126.6	143.0
Connection rate [%]	11.7	15.7	23.1	45.2	66.0	76.0	82.5
Gross Electricity Demand [GWh]	51.3	64.0	80.6	134.6	216.4	299.4	436.8
Net Electricity Demand [GWh]	35.4	44.1	56.0	95.8	160.7	228.4	340.4
Peak Demand [MW]	10.6	13.3	16.7	27.9	44.9	62.1	83.1

Table 8.2.3-2: Load and load forecast for Baghlan

Further load centers for Baghlan	Latitude N	Longitude E	
Baghlan	36°10'30"	68°46'10"	*
Khenjan	35°36'20"	68°53'10"	*
Doshi	35°36'45"	68°41'	*

* Substation coordinates estimated from map

Table 8.2.3-3: Further load centers for Baghlan

Power supply to the area around Baghlan city will be achieved by construction of a new substation along the 220 kV line from Tajikistan to Pul-e-Chomry with loop-in of one circuit.

The expected load centers on the way to the Salang Pass are served by the existing 220 kV line from Pul-e-Chomri to Chimtala and it will be possible to loop in new substations at Khenjyn and Doshi.

The proposed transformer capacity to be added to the existing and new substations and the expected loading of the transformers are given in the following Table 8.2.3-4 and Table 8.2.3-5.

	Existing and further transformer capacity [MVA] Baghlan						
		2011	2012	2015	2020	2025	2032
Pul-e-Chomri	1 x 16	16.0	16.0	16.0	16.0	16.0	16.0
Pul-e-Chomri	1 x 16				16.0	16.0	16.0
Baghlan	1 x 16		16.0	16.0	16.0	16.0	16.0
Baghlan	1 x 16				16.0	16.0	16.0
Khenjan	1 x 16			16.0	16.0	16.0	16.0
Doshi	1 x 16					16.0	16.0
Total		16	32	48	80	96	96

Table 8.2.3-4: Existing and further transformer capacity [MVA] for Baghlan

	Existing and further load at substation level [MW] for Baghlan						
		2011	2012	2015	2020	2025	2032
Pul-e-Chomri		13.3	8.4	9.3	9.0	10.4	13.9
Pul-e-Chomri					9.0	10.4	13.9
Baghlan			8.4	9.3	9.0	10.4	13.9
Baghlan					9.0	10.4	13.9
Khenjan				9.3	9.0	10.4	13.9
Doshi						10.4	13.9
Total		13.3	16.7	27.9	44.9	62.1	83.1

Table 8.2.3-5: Existing and further load at substation level [MW] for Baghlan

8.2.3.3 Overview

For staged transmission network development in Baghlan (P_03) province, a total CAPEX of $23.8m is estimated. Details of the individual stages are given in the following. The major transmission project for new Turkmenistan to Afghanistan interconnector(T_01) and the additional Hindu Kush crossing (T_02) are discussed in section 6.3 and therefore not included to the cost estimate in this chapter.

<u>Stage A up to 2015:</u>
In the first development stage, the finalization of the ongoing projects of

(i) erection of new substation 220/20 kV at Baghlan with transformer 16 MVA and loop-in of existing 220 kV line from TAJ border to Pul-e-Chomri

(ii) erection of new substation 220/20 kV at Khanjan with transformer 16 MVA and loop-in of the existing 220 kV line from Pul-e-Chomri to Chimtala
is expected.

Table 8.2.3-6 gives details of the expected CAPEX for Stage A, which adds up to $14.6m. The single-line diagram of the transmission network after implementation of Stage A is shown in **Annex 8.2.3-2**.

P_03_A Measure	Type	No	[MVA]	[km]	Cost	
new substation Baghlan	220kV	3			6.5	m$
transformer Baghlan	220/20kV	1	16		0.3	m$
new substation Khenjan	220kV	5			7.4	m$
transformer Khenjan	220/20kV	1	16		0.3	m$
Subtotal P_03_A					14.6	m$

Table 8.2.3-6: CAPEX for power system in Baghlan up to 2015

Within stage A or early in stage B finalization of the major transmission project of an additional crossing of the Hindu Kush by erection of a 500 kV line from Pul-e-Chomri to Arghandi is expected.

Stage B up to 2020:
Network development in Baghlan province required for meeting demand growth in Stage B comprises:

(i) additional transformer 220/20 kV 16 MVA at Baghlan and
(ii) additional transformer 220/20 kV 16 MVA at Pul-e-Chomri.

The CAPEX estimated for Stage B is about $2.5m.

P_03_B Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Baghlan	220kV	1			0.9	m$
transformer Baghlan	220/20kV	1	16		0.3	m$
expansion subst. Pul-e-Chomri	220kV	1			0.9	m$
transformer Pul-e-Chomri	220/20kV	1	16		0.3	m$
Subtotal P_03_B					2.5	m$

Table 8.2.3-7: Additional CAPEX for power system in Baghlan up to 2020

The single-line diagram in **Annex 8.2.3-3** shows transmission network development in Baghlan province up to 2020.

Stage C up to 2025:
With regard to transmission network development in Baghlan province, Stage C comprises the

(i) erection of substation 220/20 kV at Doshi with transformer 16 MVA and loop-in of the existing 220 kV line from Pul-e-Chomri to Chimtala.

The CAPEX for Stage C is estimated at about $6.8m, as shown in the table below.

P_03_C Measure	Type	No	[MVA]	[km]	Cost	
new substation Doshi	220kV	3			6.5	m$
transformer Doshi	220/20kV	1	16		0.3	m$
Subtotal P_03_C					6.8	m$

Table 8.2.3-8: Additional CAPEX for power system in Baghlan up to 2025

Stage D up to 2032:
In the period from 2025 to 2032, no additional measures are required for reinforcement of the transmission network in Baghlan province.

8.2.4 Balkh

8.2.4.1 Existing system

Balkh province is already supplied from the national transmission system via the 220 kV double-circuit line from Uzbekistan to Naibabad and further on to Pul-e-Chomri. Peak demand in 2011 was reported as 51 MW and the connection rate of households was over 60%. Existing substations are located at Mazar-e-Sharif and Naibabad.

Existing load centers for Balkh	Latitude N	Longitude E	
Mazar-e-Sharif	36°44'11.7"	67° 8'46.31"	*
Naibabad	36°49'3.00"	67°22'48.00"	*

* Substation coordinates given by DABS (DBS_026)

Table 8.2.4-1: Existing load centers for Balkh

The single-line diagram of the existing system is given in **Annex 8.2.4-1**.

8.2.4.2 Network expansion

The demand forecast for Balkh province indicates an increase in peak load to about 170 MW in 2032, representing a connection rate of 92.5% of households.

	Load and load forecast for Balkh						
Year	2010	2011	2012	2015	2020	2025	2032
Population [Thousand]	1194.0	1219.2					
No of Households [Thousand]	147.7	150.7	153.7	163.1	180.1	198.2	224.0
Connection rate [%]	52.3	62.7	65.6	74.2	83.0	88.0	92.5
Gross Electricity Demand [GWh]	194.8	246.2	270.9	345.0	485.3	635.5	893.2
Net Electricity Demand [GWh]	134.3	169.8	188.3	245.7	360.4	484.8	696.2
Peak Demand [MW]	40.4	51.1	56.2	71.6	100.7	131.9	169.9

Table 8.2.4-2: Load and load forecast for Balkh

In addition to expansion of the 220 kV system from Mazar-e-Sharif to Sheberghan, which is covered under the major transmission project T_01 of the TKM-AFG interconnector, installation of additional transformer capacity at existing and new substations is proposed for network development in Balkh. Currently, the additional substation at Khulm is under construction. North of Mazar-E-Sharif there is a populated area and the location Dawlat Abad could be an additional load center supplied by the 110 kV network from Mazar-e-Sharif. The coordinates for the new substations are given in the following table.

Further load centers for Balkh	Latitude N	Longitude E	
Khulm	36°41'58.00"	67°40'22.00"	*
Dawlat Abad	36°57'40"	66°49'20"	**

* Coordinates taken from planning document
** Substation coordinates estimated from map

Table 8.2.4-3: Further load centers for Balkh

The capacity of the existing and new transformers and the expected loading over the planning horizon are given in Table 8.2.4-4 and Table 8.2.4-5 below.

		Existing and further transformer capacity [MVA] Balkh					
		2011	2012	2015	2020	2025	2032
Mazar-e-Sharif	2 x 16	32.0	32.0	32.0	32.0	32.0	32.0
Mazar-e-Sharif	1 x 16	16.0	16.0	16.0	16.0	16.0	16.0
Mazar-e-Sharif	1 x 50			50.0	50.0	50.0	50.0
Mazar-e-Sharif	1 x 50				50.0	50.0	50.0
Khulm	1 x 16			16.0	16.0	16.0	16.0
Dawlat Abad	1 x 16			16.0	16.0	16.0	16.0
Total		48	48	130	180	180	180

Table 8.2.4-4: Existing and further transformer capacity [MVA] for Balkh

		Existing and further load at substation level [MW] for Balkh					
		2011	2012	2015	2020	2025	2032
Mazar-e-Sharif		34.1	37.5	17.6	17.9	23.5	30.2
Mazar-e-Sharif		17.0	18.7	8.8	9.0	11.7	15.1
Mazar-e-Sharif				27.5	28.0	36.6	47.2
Mazar-e-Sharif					28.0	36.6	47.2
Khulm				8.8	9.0	11.7	15.1
Dawlat Abad				8.8	9.0	11.7	15.1
Total		51.1	56.2	71.6	100.7	131.9	169.9

Table 8.2.4-5: Existing and further load at substation level [MW] for Balkh

8.2.4.3 Overview

For Balkh province, development of the network has already started and the expected total CAPEX required over the planning horizon is estimated at $21.2m.

The part of the double-circuit line from Mazar-e-Sharif to Sheberghan is covered under new Turkmenistan to Afghanistan interconnector project as discussed in section 6.3 and is, therefore, not included in the estimate in this section.

Stage A up to 2015:
For the first stage, the following is proposed in addition to the ongoing projects:

(i) erection of new substation 220/20 kV at Khulm with transformer 220/20 kV with a capacity of 16 MVA and loop-in of the existing line from Naibabad to Pul-e-Chomri and
(ii) installation of an additional transformer 220/20 kV with a capacity of 50 MVA at Mazar to connect an additional load center to the network; therefore:
(iii) erection of new substation 110/20 kV at Dawlat Abad with transformer 110/20 kV with a capacity of 16 MVA and construction of 110 kV line from Mazar-e-Sharif to Dawlat Abad 110 kV with a length of about 45 km.

The CAPEX required for Stage A development is estimated at $19.3m, including the ongoing projects. The single-line diagram of the resulting network is given in **Annex 8.2.4-2**.

P_04_A					
Measure	Type	No	[MVA]	[km]	Cost
new substation Khulm	220kV	3			6.5 m$
transformer Kulm	220/20kV	1	16		0.3 m$
expansion subst. Mazar-e-Sharif	220kV	1			0.9 m$
transformer Mazar-e-Sharif	220/20kV	1	50		1.0 m$
expansion subst. Mazar-e-Sharif	110kV	1			0.5 m$
new substation Dawlat Abad	110kV	2			3.3 m$
transformer Dawlat Abad	110/20	1	16		1.3 m$
110kV line Mazar - Dawlat Abad	1x3x1xACSR185			45	5.4 m$
Subtotal P_04_A					19.3 m$

Table 8.2.4-6: CAPEX for power system in Balkh up to 2015

Stage B up to 2020:

To cover load growth, it is proposed to install:

(i) additional transformer 220/20 kV at Mazar-e-Sharif with a capacity of 50 MVA.

The CAPEX required in Stage B is estimated at $1.9m. **Annex 8.2.4-3** gives the single-line diagram for network development in Balkh province.

P_04_B					
Measure	Type	No	[MVA]	[km]	Cost
expansion subst. Mazar-e-Sharif	220kV	1			0.9 m$
transformer Mazar-e-Sharif	220/20kV	1	50		1.0 m$
Subtotal P_04_B					1.9 m$

Table 8.2.4-7: Additional CAPEX for power system in Balkh up to 2020

Stage C up to 2025:

For the period 2020 to 2025, no CAPEX is required.

Stage D up to 2032:

In Stage D, no CAPEX is required. At the end of the planning horizon in 2032, the loading of the transformer will reach the limit under peak load conditions.

8.2.5 Bamyan

8.2.5.1 Existing system

Bamyan province is located in the center of Afghanistan. Currently, Bamyan province is not connected to the transmission network of Afghanistan.

8.2.5.2 Network expansion

The demand forecast for Bamyan province in Table 8.2.5-1 indicates an increase from zero to a peak load of about 28 MW in 2032.

	Load and load forecast for Bamyan						
Year	**2010**	**2011**	**2012**	**2015**	**2020**	**2025**	**2032**
Population [thousand]	411.7	418.5					
No of households [thousand]	41.9	42.6	43.5	46.1	50.9	56.0	63.3
Connection rate [%]	0.3	0.0	0.0	10.0	35.0	53.3	65.0
Gross electricity demand [GWh]	0.0	0.0	0.0	2.3	29.4	77.1	148.9
Net electricity demand [GWh]	0.0	0.0	0.0	1.6	21.8	58.8	116.1
Peak demand [MW]	0.0	0.0	0.0	0.5	6.1	16.0	28.3

Table 8.2.5-1: Load and load forecast for Bamyan

Major loads for Bamyan province are expected along the road from Bamyan via Shahidan to Yakawlang and in the valley in the northern part of the province. The preliminary locations of the additional load centers given in Table 8.2.5-2 were taken from the map.

Further load centers Bamyan	Latitude N	Longitude E	
Bamyan	34°48'30"	67!49'20"	*
Shahidan	34°48'20"	67°34'45"	*
Yakawlang	34°44'	66°58'30"	*
Ishpushta	35°18'57"	68°4'33"	*

* Substation coordinates estimated from map

Table 8.2.5-2: Further load centers for Bamyan

The additional line for crossing the Hindu Kush will be routed along the so-called resource corridor or Bamyan route from Pul-e-Chomri to Arghandi south of Kabul. This line will be part of the backbone and will be constructed as a 500 kV line. Furthermore, the coal resources in the Bamyan and Samangan area will be explored at a later stage for power generation and supply of major mining projects. One location of additional generation will be Ishpushta in Bamyan province. Another location will be Dara-i Suf in the southwest of Samangan province. For Ishpushta TPP, a substation with loop-in of the 500 kV Bamyan line will be erected. Dara-i-Suf TPP will be connected by routing a transmission line to Ishpushta to feed the additional power generation to the south.

The mining project Hajigak will be served from Bamyan substation or an additional substation along the 500 kV route to Arghandi. This investment has to be covered by the mining company. The load of Hajigak is considered as connecte to the Bamyan substation.

Power supply to the northern valley can be achieved from Ishpushta TPP. For Bamyan city and the towns along the road to the west, erection of a 500/110 kV substation and power supply at 110 kV level is planned.

The transformer capacity to be installed at the new load centers and their expected loading are given in Table 8.2.5-3 and Table 8.2.5-4 below.

	Existing and further transformer capacity [MVA] Bamyan						
		2011	2012	2015	2020	2025	2032
Bamyan	1 x 10				10.0	10.0	10.0
Shahidan	1 x 10				10.0	10.0	10.0
Yakawlang	1 x 10				10.0	10.0	10.0
Ishpushta	1 x 10						10.0
Total		0	0	0	30.0	30.0	40.0

Table 8.2.5-3: Existing and further transformer capacity [MVA] for Bamyan

	Existing and further load at substation level [MW] for Bamyan						
		2011	2012	2015	2020	2025	2032
Bamyan					2.0	5.3	7.1
Shahidan					2.0	5.3	7.1
Yakawlang					2.0	5.3	7.1
Ishpushta							7.1
Total		0.0	0.0	0.0	6.1	16.0	28.3

Table 8.2.5-4: Existing and further load at substation level [MW] for Bamyan

8.2.5.3 Overview

The staged development of the transmission network for power supply to Bamyan province (P_05) will require a CAPEX of about $41.5m. It is expected that, up to 2020, construction of the 500 kV line from Pul-e-Chomri to Arghandi will be finalized. The details of this major transmission project are discussed in section 8.2.3.

The estimated costs of tie-in of Ishpushta coal-fired power plant (GN_22) are about $81m.

Stage A up to 2015:
Power supply in Bamyan will be possible after construction of the new transmission line crossing the Hindu Kush along the Bamyan route. Therefore, no CAPEX is expected in the first stage.

Stage B up to 2020:
For the period 2015 to 2020,

(i) erection of 500/110 kV substation at Bamyan Tie In with interbus transformer 25 MVA
(ii) erection of 110/20 kV substation at Bamyan with transformer capacity 10 MVA and 110 kV line from Bamyan Tie In to Bamyan with a length of about 15 km

(iii) erection of 110/20 KV substation at Shahidan with transformer capacity 10 MVA and 110 kV line from Bamyan to Shahidan with a length of about 25 km
(vi) erection of 110/20 KV substation at Yakawlang with transformer capacity 10 MVA and 110 kV line from Shahidan to Yakawlang with a length of about 60 km

is expected with estimated CAPEX for development Stage B of about $41.5m, as given in the table below.

P_05_B Measure	Type	No	[MVA]	[km]	Cost	
new substation Bamyan Tie In	500kV	3			14.8	m$
new substation Bamyan Tie In	110kV	2			3.3	m$
interbus transformer Bamyan TI	500/110kV	1	25		0.5	m$
new substation Bamyan	110kV	3			3.5	m$
transformer Bamyan	110/20kV	1	10		0.2	m$
new substation Shahidan	110kV	3			3.5	m$
transformer Shahidan	110/20kV	1	10		0.2	m$
new substation Yakawlang	110kV	2			3.3	m$
transformer Yakawlang	110/20kV	1	10		0.2	m$
110kV line Bamyan TI - Bamyan	1x3x1xACSR185			15	1.8	m$
110kV line Bamyan - Shahidan	1x3x1xACSR185			25	3.0	m$
110 kV line Shahidan - Yakawlang	1x3x1xACSR185			60	7.2	m$
Subtotal P_05_B					41.5	m$

Table 8.2.5-5: Additional CAPEX for power system in Bamyan up to 2020

The single-line diagram for the transmission network of Bamyan province after implementation of Stage B is given in **Annex 8.2.5-3**.

Stage C up to 2025:
For the period from 2020 to 2025, no additional CAPEX is required for transmission network development in Bamyan province.

Stage D up to 2032:
For the period 2025 to 2032, the power supply for the load center at Ishpushta will be from the new power plant at Ishpushta at 20 kV level. Therefore, no CAPEX is required for the transmission network for supply of loads.

In any case, integration of Ishpushta TPP and Dara-i-Suf TPP into the system is expected. For integration of Ishpushta TPP (GN_22), the

(i) erection of 500 kV substation at Ishpushta with two step-up transformers 500/20 kV each for generators 240 MVA

is required and the CAPEX is estimated at about $81m.
Network integration of Dara-i-Suf TPP is discussed in section 8.2.29 of Samangan province.

G_22_D	Additional CAPEX up to 2032					
Measure	Type	No	[MVA]	[km]	Cost	
new substation Ishpushta	500kV	4			72.0	m$
transformer Ishpushta	500/20kV	2	240		9.1	m$
Subtotal G_22_D					81.1	m$

Table 8.2.5-6: CAPEX for network integration of Ishpushta TPP up to 2032

The network integration of Dara-i-Suf TPP is discussed in section 0.

Annex 8.2.5-5 shows the transmission network for Bamyan after installation of the equipment for Stage D.

8.2.6 Daykundi

8.2.6.1 Existing system

The province of Daykundi is located in central Afghanistan. Currently, there is no power supply from the national grid of Afghanistan.

8.2.6.2 Network expansion

Peak demand in Daykundi is expected at about 30 MW with a connection rate of 65% of households.

	Load and load forecast for Daykundi						
Year	2010	2011	2012	2015	2020	2025	2032
Population [Thousand]	424.1	431.3					
No of Households [Thousand]	42.6	43.4	44.3	47.0	51.9	57.1	64.5
Connection rate [%]	0.0	0.0	0.0	10.0	35.0	53.3	65.0
Gross Electricity Demand [GWh]	0.0	0.0	0.0	2.3	29.9	78.5	151.7
Net Electricity Demand [GWh]	0.0	0.0	0.0	1.6	22.2	59.9	118.2
Peak Demand [MW]	0.0	0.0	0.0	0.5	6.2	16.3	28.9

Table 8.2.6-1: Load and load forecast for Daykundi

The population is spread over the mountainous area, but the major load is expected to be around Nili, the capital of the province, and around Gizab.

Further load centers for Daykundi	Latitude N	Longitude E	
Nili	33°43'	66°8'20"	*
Gizab	33°23'40"	66°12'40"	*

* Substation coordinates estimated from map

Table 8.2.6-2: Further load centers for Daykundi

The transformer capacity to be installed at the new substations and the expected loading of the transformers are given in the following tables.

		Existing and further transformer capacity [MVA] Daykundi					
		2011	2012	2015	2020	2025	2032
Nili	2 x 10						20.0
Gizab	2 x 10						20.0
Total		0	0	0	0.0	0.0	40.0

Table 8.2.6-3: Existing and further transformer capacity [MVA] for Daykundi

	Existing and further load at substation level [MW] for Daykundi						
		2011	2012	2015	2020	2025	2032
Nili							14.4
Gizab							14.4
Total		0.0	0.0	0.0	0.0	0.0	28.9

Table 8.2.6-4: Existing and further load at substation level [MW] for Daykundi

With construction of Olambagh HPP between 2025 and 2032, connection of this load center to the national grid will be possible. The routing of the 110 kV line between Olambagh and Nili must be chosen in a way to connect other larger towns, such as Gizab.

For the transition period, this remote province will have to use local supply facilities, also in pilot phase.

8.2.6.3 Overview

The connection of Daykundi province will be possible after commissioning of Olambagh HPP. Therefore, no CAPEX is expected in Stages A to C for this province.
Total CAPEX is expected at about $24.2m (P_06).

Stage D up to 2032:
For stage D, the following installations are proposed:

(i) erection of substation 110/20 kV at Gizab with two transformers each with a capacity of 10 MVA and construction of 110 kV transmission line from Olambagh to Gizab with a length of about 90 km
(ii) erection of substation 110/20 kV at Nili with two transformers each with a capacity of 10 MVA and construction of 110 kV transmission line from Gizab to Nili with a length of about 40 km.

The CAPEX for development Stage D is estimated at about $24.2m and the single-line diagram for the transmission network in Daykundi province is given in **Annex 8.2.6-5**.

P_06_D						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Olambagh	110kV	1			0.5	m$
new substation Gizab	110kV	4			3.7	m$
transformer Gizab	110/20kV	2	10		0.4	m$
new substation Nili	110kV	3			3.5	m$
transformer Nili	110/20kV	2	10		0.4	m$
110kV line Olambagh - Gizab	1x3x1xACSR185			90	10.8	m$
110kV line Gizab - Nili	1x3x1xACSR185			40	4.8	m$
Subtotal P_06_D					24.2	m$

Table 8.2.6-5:Additional CAPEX for power system in Daykundi up to 2032

8.2.7 Farah

8.2.7.1 Existing system

Farah province is located in the southwest of Afghanistan at the border with Iran and has no connection to the national grid. Currently, only about 6% of households are connected to the isolated power supply.

8.2.7.2 Network expansion

The demand forecast indicates an increase up to a peak demand of 42 MW in 2032, when the connection rate will reach 70%.

	Load and load forecast for Farah						
Year	**2010**	**2011**	**2012**	**2015**	**2020**	**2025**	**2032**
Population [Thousand]	466.3	474.3					
No of Households [Thousand]	48.9	49.8	50.8	53.9	59.6	65.6	74.1
Connection rate [%]	0.9	5.6	10.6	25.4	50.0	58.3	70.0
Gross Electricity Demand [GWh]	0.2	0.9	2.6	14.4	70.2	117.4	219.2
Net Electricity Demand [GWh]	0.1	0.6	1.8	10.3	52.1	89.6	170.9
Peak Demand [MW]	0.0	0.2	0.5	3.0	14.6	24.4	41.7

Table 8.2.7-1: Load and load forecast for Farah

The population is spread over the province from River Farah Rud to the west. Major loads can be expected along the River Farah Rud, although these loads are also spread over the total extent of the province. The province of Farah is far away from existing electrical networks. The direct distance between Farah city and Herat in the northwest is about 200 km and the direct distance to Helmand in the east is about 240 km. Connection of the province to the national grid may be possible if the ring is closed by construction of a connection line from Herat to Kandahar. This link is not expected within the planning horizon.

Therefore, a local power supply system using renewable resources and/or combined supply options with generation by diesel generator sets is expected for Farah province.

The expected load centers apart from the capital of the province could not yet be defined.

Further load centers for Farah	Latitude N	Longitude E	
Farah	TBD	TBD	
Load Region 2	TBD	TBD	
Load Region 3	TBD	TBD	
Load Region 4	TBD	TBD	
Load Region 5	TBD	TBD	
Load Region 6	TBD	TBD	
Load Region 7	TBD	TBD	
Load Region 8	TBD	TBD	

Table 8.2.7-2: Further load centers for Farah

For these load centers, the expected peak load to be covered by isolated operating systems is given in the following table.

	Existing and further load at substation level [MW] for Farah						
		2011	2012	2015	2020	2025	2032
Farah				3.0	3.6	4.1	4.6
Farah					3.6	4.1	4.6
Load Region 2					3.6	4.1	4.6
Load Region 3					3.6	4.1	4.6
Load Region 4						4.1	4.6
Load Region 5						4.1	4.6
Load Region 6							4.6
Load Region 7							4.6
Load Region 8							4.6
Total		0.0	0.0	3.0	14.6	24.4	41.7

Table 8.2.7-3: Existing and further load at substation level [MW] for Farah

8.2.7.3 Overview

For the province of Farah, it is advisable to start with single house power supply systems. Larger units can be installed at a later stage for towns. The transmission network will not be developed in Farah province. It is advisable to use distributed units for households in towns and cities. Details of the requirements of the different systems could not be given at the stage of the master plan, but should be developed as part of a detailed investigation in the province.

Stage A up to 2015:
Up to 2015, installation of

(i) distribution networks for Farah with local isolated generation

is expected.

Stage B up to 2020:
Up to 2020, installation of

(i) expansion of Farah distribution network and additional local isolated generation in Farah
(ii) distribution system with local isolated generation for a second load center
(iii) distribution system with local isolated generation for a third load center

is expected.

Stage C up to 2025:
For 2025, installation of

(i) distribution system with local isolated generation for a fourth load center
(ii) distribution system with local isolated generation for a fifth load center

is expected.

Stage D up to 2032:
In stage D of development, installation of

(i) distribution system with local isolated generation for a sixth load center
(ii) distribution system with local isolated generation for a seventh load center
(iii) distribution system with local isolated generation for an eighth load center

is expected.

Latest information received from the Ministry during the workshop in February 2013 indicates that Iran is willing to build a 220 kV line to Farah province. This will then also an option to complement power supply for that region.

8.2.8 Faryab

8.2.8.1 Existing system

The Faryab area is currently supplied together with Jowzjan and Sar-e Pul from Turkmenistan via a 110 kV line. The length of the line on Afghan territory is about 42 km. On the Turkmen side, the distance from the border to the nearest power station is about 300 km, of which about 250 km is at the 110 kV level. Along this route, the voltage drop is dramatic and, owing to voltage collapse, it is not possible for the entire demand in Faryab, Jowzjan and Sar-e Pul to be served.

The receiving substation is Andkhoy, which is the starting point of the transmission system in Faryab region.

The existing system consists of the following 110 kV substations:

Existing load centers for Faryab	Latitude N	Longitude E	
Andkhoy	36°56'36.8"	67° 8'46.3"	*
Sherin Tagab	36°14'30"	64°51'50"	**
Juma Bazar	36° 4'10"	64°50'20"	**
Maimana	35°55'20"	64°47'10"	**

* Substation coordinates by DABS (DBS_026)

** Substation coordinates estimated from map

Table 8.2.8-1: Existing load centers for Faryab

The single-line diagram for the existing transmission system in Faryab province is given in **Annex 8.2.8-1**.

The demand for 2012 for Faryab is 23 MW during peak load time, but only about 56% of loads can be served, considering a power factor of 0.9. The voltage level during peak load time is 67% of nominal voltage.

The losses along the line are currently very high. During peak load time, the losses are about 21%.

Additional loads cannot be supplied, although the corresponding transformer capacities for the step down from 110 kV are available and transmission network reinforcement is urgently required.

8.2.8.2 Network expansion

Electrical peak demand in Faryab province will increase from 23 MW in 2012 to 93 MW in 2032 for the base case scenario. The connection rate will increase from currently 53% to 92.5% in 2032.

Details of the demand forecast for Faryab are given in the following table:

	Load and load forecast for Faryab						
Year	**2010**	**2011**	**2012**	**2015**	**2020**	**2025**	**2032**
Population [Thousand]	915.8	931.8					
No of Households [Thousand]	98.9	100.8	102.8	109.1	120.5	132.7	149.9
Connection rate [%]	43.5	53.0	57.5	71.0	83.0	88.0	92.5
Gross Electricity Demand [GWh]	85.7	95.2	111.1	167.7	264.8	343.4	486.9
Net Electricity Demand [GWh]	59.1	65.6	77.3	119.5	196.7	261.9	379.5
Peak Demand [MW]	17.8	19.8	23.1	34.8	55.0	71.3	92.6

Table 8.2.8-2: Load and load forecast for Faryab

A comparison of transformer capacity installed in the region and the predicted loads shows that, for 2025, additional substations or transformer capacity at existing substations will be required. Network expansion from Maimana to the south will increase the distribution area and will take into account the fact that the additionally connected households are not necessarily concentrated in the major towns. Possible new load centers are the areas of Almar, Qaisar and Belcheragh, which could be served via 110 kV lines from Miamana. An initial estimate of substation locations for the further load centers is given in the following table:

Further load centers for Faryab	Latitude N	Longitude E	
Almar	35°50'40"	64°32'0"	*
Belcheragh	35°50'20"	65°14'25"	*
Qaisar	35°41'30"	64°17'50"	*

* Substation coordinates estimated from map

Table 8.2.8-3: Further load centers for Faryab

Improvement of the feed-in to Andkhoy is urgently required for a secure power supply to the Faryab region. Connection at the 220 kV level will make it possible to meet current demand as well as expected future growth.

		Existing and further transformer capacity [MVA] Faryab					
		2011	**2012**	**2015**	**2020**	**2025**	**2032**
Andkhoy	1 x 10	10.0	10.0	10.0	10.0	10.0	10.0
Andkhoy	1 x 10						10.0
Sherin Tagab	2 x 10	20.0	20.0	20.0	20.0	20.0	20.0
Juma Bazar	2 x 4	8.0	8.0	8.0	8.0	8.0	8.0
Maimana	2 x 16	32.0	32.0	32.0	32.0	32.0	32.0
Almar	1 x 10				10.0	10.0	10.0
Belcheragh	1 x 10				10.0	10.0	10.0
Qaisar	1 x 10				10.0	10.0	10.0
Total		70	70	70	100	100	110

Table 8.2.8-4: Existing and further transformer capacity [MVA] for Faryab

	Existing and further load at substation level [MW] for Faryab						
		2011	2012	2015	2020	2025	2032
Andkhoy		2.8	3.3	5.0	5.5	7.1	8.4
Andkhoy							8.4
Sherin Tagab		5.6	6.6	9.9	11.0	14.3	16.8
Juma Bazar		2.3	2.6	4.0	4.4	5.7	6.7
Maimana		9.0	10.5	15.9	17.6	22.8	26.9
Almar					5.5	7.1	8.4
Belcheragh					5.5	7.1	8.4
Qaisar					5.5	7.1	8.4
Total		19.8	23.1	34.8	55.0	71.3	92.6

Table 8.2.8-5: Existing and further load at substation level [MW] for Faryab

With utilization of the transformer capacity installed along the 110 kV line from Andkhoy to Maimana, the voltage drop along this line section will also increase together with the resulting losses. Therefore, additional transmission capacity will be required. There are two possibilities: one will be an expansion of the 110 kV network, and the other will be the introduction of the 220 kV voltage level in the region by adding a 220 kV substation at Maimana and a 220 kV line from Andkhoy to Maimana, length about 140 km. This will also be the first part of the Herat interconnection line, which is discussed in section 6.3.

8.2.8.3 Overview

For the province of Faryab, the following network reinforcement will be required in order to secure the current and future power supply. Total CAPEX is expected to be about $38.3m. Two major transmission projects are partially located in Faryab province. These projects are discussed separately.

Stage A up to 2015:
It is expected that the TKM-AFG interconnector will be commissioned and the first part of the Herat interconnector will be constructed.
For power supply in Faryab province, it is proposed to

(i) install a new substation 220 kV at Maimana with interbus transformer 220/110 kV with a capacity of 50 MVA and loop-in of the Herat interconnector.

The estimated cost of this reinforcement is $9m and will include a complete 220 kV substation for further loop-in of both circuits of the interconnector to Herat. **Annex 8.2.8-2** gives the single-line diagram of network development up to 2015 for Faryab province.

P_08_A					
Measure	Type	No	[MVA]	[km]	Cost
new substation Maimana	220kV	5			7.4 m$
expansion subst. Maimana	110kV	1			0.5 m$
transformer Maimana	220/110kV	1	50		1.0 m$
Subtotal P_08_A					9.0 m$

Table 8.2.8-6: CAPEX for power system in Faryab up to 2015

Stage B up to 2020:

For the period 2015 to 2020, it is expected that the second stage of the TKM-AFG interconnector, including the 220 kV double-circuit line to be established between Sheberghan and Andkhoy, will be constructed and that the Herat interconnector will be extended as far as Badghis province.

To cover load growth in Faryab, it is necessary to add additional substations to the grid as follows:

(i) erection of new substation 220 kV at Almar with transformer 220/20 kV with a capacity of 10 MVA

(ii) erection of new substation 220 kV at Qaisar with transformer 220/20 kV with a capacity of 10 MVA

(iii) erection of new substation 110 kV at Belcheragh with transformer 110/20 kV with a capacity of 10 MVA and 110 kV transmission line from Maimana to Belcheragh with a length of 50 km.

The CAPEX for development Stage B is estimated at $28.6m. The single-line diagram in **Annex 8.2.8-3** gives an overview of the expanded network in Faryab.

P_08_B					
Measure	Type	No	[MVA]	[km]	Cost
new substation Almar	220kV	5			7.4 m$
transformer Almar	220/20kV	1	10		0.2 m$
new substation Qaisar	220kV	5			7.4 m$
transformer Qaisar	220/20kV	1	10		0.2 m$
expansion subst. Maimana	110kV	1			0.5 m$
new substation Belcheragh	110kV	2			6.6 m$
transformer Belcheragh	110/20kV	1	10		0.2 m$
110kV line Maimana-Belcheragh	1x3x1xACSR185			50	6.0 m$
Subtotal P_08_B					28.6 m$

Table 8.2.8-7: Additional CAPEX for power system in Faryab up to 2020

Stage C up to 2025:

For this period, no further reinforcement of the transmission network is expected.

Stage D up to 2032:

In the period 2025 to 2032, the second circuit of the Herat interconnector (T_05) will be installed.

To meet demand growth, the installation of an

(i) additional transformer 110/20 kV at Andkhoy with a capacity of 10 MVA will be required.

The required capital expenditure for development Stage D will be about $0.7m. The development of the network in Faryab province up to 2032 is given in **Annex 8.2.8-5**.

P_08_D Measure	Type	No	[MVA]	[km]	Cost	
expansion subst. Andkhoy	110kV	1			0.5	m$
transformer Andkhoy	110/20kV	1	10		0.2	m$
Subtotal P_08_D					0.7	m$

Table 8.2.8-8: Additional CAPEX for power system in Faryab up to 2032

8.2.9 Ghazni

8.2.9.1 Existing system

Currently, Ghazni province is not connected to the national grid. The connection rate of households was 3% in 2011.

8.2.9.2 Network expansion

Peak load for Ghazni province is expected at 100 MW and the connection rate will reach 70% in 2032, as given in Table 8.2.9-1.

	Load and load forecast for Ghazni						
Year	**2010**	**2011**	**2012**	**2015**	**2020**	**2025**	**2032**
Population [Thousand]	1130.1	1149.4					
No of Households [Thousand]	116.6	118.9	121.3	128.7	142.1	156.5	176.8
Connection rate [%]	2.4	3.0	8.3	23.9	50.0	58.3	70.0
Gross Electricity Demand [GWh]	2.2	2.9	8.5	32.4	167.5	280.2	523.2
Net Electricity Demand [GWh]	1.5	2.0	5.9	23.1	124.4	213.7	407.8
Peak Demand [MW]	0.5	0.6	1.8	6.7	34.8	58.2	99.5

Table 8.2.9-1: Load and load forecast for Ghazni

The load centers in Ghazni province are along the ring road A1 from Kabul to Kandahar and the tentatively proposed locations of the new substations are given in the following table.

Further load centers for Ghazni	Latitude N	Longitude E	
Ghazni	33°33'30"	68°27'30"	*
Quarabagh	33°10'40"	68° 6'30"	*
Gelan	32°43'50"	67°38'40"	*

* Substation coordinates estimated from map

Table 8.2.9-2: Further load centers for Ghazni

Electrification could come from the NEPS to SEPS connector. One substation will be at the capital, Ghazni. This substation will also be used to feed a load at Sharan in Paktika province at the 110 kV level. Two other substations along the NEPS to SEPS connector will be at Quarabagh and Gelan. Gelan will also be used to feed a load in Paktika province.

The capacities of the transformers to be installed at the new substations and the expected loading of the transformers are given in the following tables.

	Existing and further transformer capacity [MVA] Ghazni						
		2011	2012	2015	2020	2025	2032
Ghazni	2 x 16				32.0	32.0	32.0
Ghazni	1 x 16					16.0	16.0
Quarabagh	1 x 16				16.0	16.0	16.0
Quarabagh	1 x 16						16.0
Gelan	1 x 16				16.0	16.0	16.0
Gelan	1 x 16						16.0
Total		0	0	0	64.0	80.0	112.0

Table 8.2.9-3: Existing and further transformer capacity [MVA] for Ghazni

	Existing and further load at substation level [MW] for Ghazni						
		2011	2012	2015	2020	2025	2032
Ghazni					17.4	23.3	28.4
Ghazni						11.6	14.2
Quarabagh					8.7	11.6	14.2
Quarabagh							14.2
Gelan					8.7	11.6	14.2
Gelan							14.2
Total		0.0	0.0	0.0	34.8	58.2	99.5

Table 8.2.9-4: Existing and further load at substation level [MW] for Ghazni

8.2.9.3 Overview

Staged development of the Ghazni region will be along the NEPS to SEPS interconnector and the required CAPEX is estimated at about $38.8m. The major transmission project NEPS to SEPS interconnector (T_03) was already discussed in section 6.3.

Stage A up to 2015:
The interconnector will be available after 2015. Therefore, no CAPEX will be possible for the period up to 2015.

Stage B up to 2020:
Development of the transmission system in Ghazni up to 2020 will require the following installations:

(i) erection of substation 220/110/20 kV at Ghazni with interbus transformer 220/110 kV with a capacity of 25 MVA, one transformer 220/20 kV with a capacity of 16 MVA and one transformer 110/20 kV with a capacity of 16 MVA and loop-in of the new NEPS to SEPS interconnector
(ii) erection of substation 220/20 kV at Quarabagh with transformer capacity of 16 MVA and loop-in to the new NEPS to SEPS interconnector
(iii) erection of substation 220/110/20 kV at Gelan with interbus transformer 220/110 kV with a capacity of 25 MVA and one transformer 110/20 kV with a capacity of 16 MVA and loop-in of the new NEPS to SEPS interconnector.

CAPEX for the measures in Stage B is estimated at about $31.5m and the single-line diagram of the transmission network in Ghazni for development Stage B is given in **Annex 8.2.9-3**. For the substation along the NEPS to SEPS interconnector full equipment for looping in of two circuits is considered.

P_09_B Measure	Type	No	[MVA]	[km]	Cost	
new substation Ghazni	220kV	6			7.8	m$
new substation Ghazni	110kV	2			3.3	m$
transformer Ghazni	220/110kV	1	25		0.5	m$
transformer Ghazni	220/20kV	1	16		0.3	m$
transformer Ghazni	110/20	1	16		0.3	m$
new substation Quarabagh	220kV	5			7.4	m$
transformer Quarabagh	220/20kV	1	16		0.3	m$
new substation Gelan	220kV	5			7.4	m$
new substation Gelan	110kV	2			3.3	m$
transformer Gelan	220/110kV	1	25		0.5	m$
transformer Gelan	110/20kV	1	16		0.3	m$
Subtotal P_09_B					31.5	m$

Table 8.2.9-5: Additional CAPEX for power system in Ghazni up to 2020

<u>Stage C up to 2025:</u>
To meet load growth up to 2025, an

(i) Additional transformer at substation 220/20 kV at Ghazni with a capacity of 16 MVA is planned.

This will require a CAPEX of about $1.2m and the resulting network configuration is given in **Annex 8.2.9-4** considering also the second circuit of the NEPS to SEPS interconnector.

P_09_C Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Ghazni	220kV	1			0.9	m$
transformer Ghazni	220/20kV	1	16		0.3	m$
Subtotal P_09_C					1.2	m$

Table 8.2.9-6: Additional CAPEX for power system in Ghazni up to 2025

<u>Stage D up to 2032:</u>
To meet load growth up to 2032, an

(i) additional interbus transformer at substation 220/110 kV at Ghazni with a capacity of 25 MVA
(ii) additional transformer at substation 220/20 kV at Quarabagh with a capacity of 16 MVA
(iii) additional interbus transformer at substation 220/110 kV at Gelan with a capacity of 25 MVA and additional transformer 110/20 kV 16 MV at substation Gelan

will be required. This will require a CAPEX of about $6m and the resulting network configuration is given in **Annex 8.2.9-5**.

P_09_D Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Ghazni	220kV	1			0.9	m$
expansion substation Ghazni	110kV	1			0.5	m$
transformer Ghazni	220/110kV	1	25		0.5	m$
expansion subst. Quarabagh	220kV	1			0.9	m$
transformer Quarabagh	220/20kV	1	16		0.3	m$
expansion substation Gelan	220kV	1			0.9	m$
expansion substation Gelan	110kV	2			1.1	m$
transformer Gelan	220/110kV	1	25		0.5	m$
transformer Gelan	110/20kV	1	16		0.3	m$
Subtotal P_09_D					6.0	m$

Table 8.2.9-7: Additional CAPEX for power system in Ghazni up to 2032

8.2.10 Ghor

8.2.10.1 Existing system

Ghor province is located in central Afghanistan, towards the northwest. Ghor province has no network. The region is not supplied from the national system.

8.2.10.2 Network expansion

The load forecast indicates a significant load from 2015 onwards, reaching 55 MW in 2032 with a connection rate of 70%.

	Load and load forecast for Ghor						
Year	2010	2011	2012	2015	2020	2025	2032
Population [Thousand]	635.7	646.3					
No of Households [Thousand]	64.0	65.3	66.6	70.7	78.0	85.9	97.0
Connection rate [%]	1.6	2.2	7.5	23.4	50.0	58.3	70.0
Gross Electricity Demand [GWh]	0.4	0.6	2.9	17.4	91.9	153.8	287.1
Net Electricity Demand [GWh]	0.3	0.4	2.0	12.4	68.3	117.3	223.8
Peak Demand [MW]	0.1	0.1	0.6	3.6	19.1	31.9	54.6

Table 8.2.10-1: Load and load forecast for Ghor

The capital of Ghor is Chaghcharan. Power supply could be achieved by connection of a new substation at Chaghcharan to Salma HPP by a 220 kV line. Electrification of Ghor could be established at the 110 kV level from the central substation at Chaghcharan. The tentative location of the substation is given in the following table.

Further load centers for Ghor	Latitude N	Longitude E	
Chaghcharan	34°31'3"	65°15'17"	*

* Substation coordinates estimated from map

Table 8.2.10-2: Further load centers for Ghor

The locations of other load centers have not yet been identified. Therefore, for planning, it is assumed that the load will be concentrated at Chaghcharan. With regard to transformer size, it is recommended to use smaller units to provide an opportunity for decentralized use with a part of the 110 kV overhead line between the feeder of the substation and the transformer itself. Table 8.2.10-3 gives an overview of transformer capacity and Table 8.2.10-4 shows the expected loading over the planning horizon.

		Existing and further transformer capacity [MVA] Ghor					
		2011	2012	2015	2020	2025	2032
Chaghcharan	4 x 10				40.0	40.0	40.0
Chaghcharan	2 x 10						20.0
Total		0	0	0	40.0	40.0	60.0

Table 8.2.10-3: Existing and further transformer capacity [MVA] for Ghor

	Existing and further load at substation level [MW] for Ghor						
		2011	2012	2015	2020	2025	2032
Chaghcharan					19.1	31.9	36.4
Chaghcharan							18.2
Total		0.0	0.0	0.0	19.1	31.9	54.6

Table 8.2.10-4: Existing and further load at substation level [MW] for Ghor

8.2.10.3 Overview

Development of the network in Ghor will require a total CAPEX of about $63.2m (P_10).

Stage A up to 2015:
Chor province will be connected to Salma substation at the new hydropower plant. This connection will be possible in the second stage of the planning horizon. Therefore, no CAPEX will be possible in Stage A.

Stage B up to 2020:
For network development in Stage B, the following is proposed:

(i) erection of new substation 220/110/20 kV at Chaghcharan with two interbus transformers 220/110 kV each with a capacity of 20 MVA and four transformers 110/20 kV each with a capacity of 10 MVA and construction of a transmission line from Salam to Chaghcharan with a length of about 135 km.

The 110/20 kV transformers need not necessarily be installed at Chaghcharan and can also be installed at other places within a further 110 kV network. Transmission lines 110 kV to other load centers must be defined. They are included with an average of 30 km per feeder.

The CAPEX required for Stage B is estimated at about $53.2m and the single-line diagram for the transmission system in Ghor is given in **Annex 8.2.10-3**.

P_10_B Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Salma	220kV	1			0.9	m$
new substation Chaghcharan	220kV	3			6.5	m$
new substation Chaghcharan	110kV	6			4.1	m$
transformer Chaghcharan	220/110kV	2	20		0.8	m$
transformer Chaghcharan	110/20kV	4	10		0.8	m$
220kV line Salma - Chaghcharan	1x3x1xACSR300			135	25.7	m$
110kV line Chor 4x 30km	1x3x1xACSR185			120	14.4	m$
Subtotal P_10_B					53.2	m$

Table 8.2.10-5: Additional CAPEX for power system in Ghor up to 2020

Stage C up to 2025:
For the period 2020 to 2025, no CAPEX is planned for the transmission network in Ghor.

Stage D up to 2032:
To meet load growth up to 2032, an

(i) additional interbus transformer 220/110 kV with a capacity of 20 MVA and two additional transformers and 110/20 kV each with a capacity of 10 MVA at Chaghcharan will be required.

The CAPEX for Stage D is estimated at about $10m. This estimate also includes a portion for a transmission lines on the 110 kV level from the feeders to the transformer. **Annex 8.2.10-5** shows the single-line diagram for the transmission system in Ghor province for 2032.

P_10_D						
Measure	Type	No	[MVA]	[km]	Cost	
expansion subst. Chaghcharan	220kV	1			0.9	m$
expansion subst. Chaghcharan	110kV	2			1.1	m$
transformer Chaghcharan	220/110kV	1	20		0.4	m$
transformer Chaghcharan	110/20kV	2	10		0.4	m$
110kV line Chor 2x 30km	1x3x1xACSR185			60	7.2	m$
Subtotal P_10_D					10.0	m$

Table 8.2.10-6: Additional CAPEX for power system in Ghor up to 2032

8.2.11 Helmand

8.2.11.1 Existing system

Currently, Helmand is served by a 110 kV network along the populated area from Kajaki to Lashkargah. The system is supplied from Kajaki hydropower plant and by the connection at Durai Junction from the 110 kV line from Kandahar. The single-line diagram of the existing system is given in **Annex 8.2.11-1**. The locations of the existing substations were estimated from the maps as follows:

Existing load centers for Helmand	Latitude N	Longitude E	
Kajaki HPP	32°19'30"	65°7'	*
Musa Qala	32°21'50"	64°47'20"	*
Sangin North	32° 4'24"	64°50'	*
Lashkargah	31°36'50"	64°23'10"	*
Dorahi Junction	31°45'	64°43'30"	*

* Substation coordinates estimated from map

Table 8.2.11-1: Existing load centers for Helmand

Within the existing system, about 30% of households in Helmand province are connected and peak demand is reported at 7.4 MW.

8.2.11.2 Network expansion

Load will increase in Helmand province up to 2032 to a peak load of about 70 MW with 82.5% of households being connected. The demand forecast for the province is given in the following table.

	Load and load forecast for Helmand						
Year	2010	2011	2012	2015	2020	2025	2032
Population [Thousand]	850.2	864.6					
No of Households [Thousand]	88.3	90.1	91.9	97.5	107.6	118.5	133.9
Connection rate [%]	25.1	29.7	36.4	56.6	73.0	78.0	82.5
Gross Electricity Demand [GWh]	27.7	35.6	48.7	102.5	202.8	261.1	364.1
Net Electricity Demand [GWh]	19.1	24.6	33.8	73.0	150.6	199.2	283.8
Peak Demand [MW]	5.8	7.4	10.1	21.3	42.1	54.2	69.3

Table 8.2.11-2: Load and load forecast for Helmand

Network expansion is expected along the River Helmand from Kajaki up to the south of Lashkargah. The existing substations at Musa Qala and Sangi North will be reinforced and an additional substation at Sangin South along the existing 110 kV line will be integrated near the Durai Junction. The tentative location of the new substation is given in the following table.

Further load centers for Helmand	Latitude N	Longitude E	
Sangin South	31°48'25"	64°34'10"	*

* Substation coordinates estimated from map

Table 8.2.11-3: Further load centers for Helmand

Load growth in the region will require the installation of additional transformer capacity at the existing and new substation locations. Table 8.2.11-4 and Table 8.2.11-5 show the expected capacity and loading of the transformers.

	Existing and further transformer capacity [MVA] Helmand						
		2011	**2012**	**2015**	**2020**	**2025**	**2032**
Kajaki HPP							
Musa Qala	1 x 10	10.0	10.0	10.0	10.0	10.0	10.0
Musa Qala	1 x 16					16.0	16.0
Sangin North	1 x 5	5.0	5.0	5.0	5.0	5.0	5.0
Sangin North	1 x 16				16.0	16.0	16.0
Lashkargah	3 x 3.3	9.9	9.9	9.9	9.9	9.9	9.9
Lashkargah	1 x 16				16.0	16.0	16.0
Dorahi Junction							
Sangin South	1 x 16			16.0	16.0	16.0	16.0
Total		24.9	24.9	40.9	72.9	88.9	88.9

Table 8.2.11-4: Existing and further transformer capacity [MVA] for Helmand

	Existing and further load at substation level [MW] for Helmand						
		2011	**2012**	**2015**	**2020**	**2025**	**2032**
Kajaki HPP							
Musa Qala		3.0	4.1	5.2	5.8	6.1	7.8
Musa Qala						9.8	12.5
Sangin North		1.5	2.0	2.6	2.9	3.0	3.9
Sangin North					9.2	9.8	12.5
Lashkargah		2.9	4.0	5.2	5.7	6.0	7.7
Lashkargah					9.2	9.8	12.5
Dorahi Junction							
Sangin South				8.3	9.2	9.8	12.5
Total		7.4	10.1	21.3	42.1	54.2	69.3

Table 8.2.11-5: Existing and further load at substation level [MW] for Helmand

Rehabilitation of Kajaki HPP and installation of a third 18.5 MW unit is expected by 2015. Also, the integration of Kajaki Addition with 100 MW is required within the planning horizon.

8.2.11.3 Overview

Network development is proposed according to the following stages and will result in a CAPEX for reinforcement of the transmission system of about $18.7m (P_11). Network integration of Kajaki Expansion (GN_02) will require CAPEX of about $1.1m and Kajaki Addition HPP (GN_06) will require a CAPEX of about $14.8m.

Stage A up to2015:
For the period up to 2015, the following measures are proposed for the transmission network:

(i) erection of new substation at Sangin South with transformer 110/20 kV with a capacity of 16 MVA connected via 110 kV line to Durai Junction with a length of about 35 km.

The measures in this stage will require a CAPEX of about $8.4m.

P_11_A						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Durai Junction	110kV	1			0.5	m$
new substation Sangin South	110kV	2			3.3	m$
transformer Sangin South	110/20kV	1	16		0.3	m$
110kV line Durai Junc. - Sangin South	1x3x1xACSR185			35	4.2	m$
Subtotal P_11_A					8.4	m$

Table 8.2.11-6: CAPEX for power system in Helmand up to 2015

The network integration of Kajaki Extension (GN_02) will cost about $1.1m and it will be necessary to install an

(i) additional step-up transformer at Kajaki HPP

G_02_A	CAPEX up to 2015					
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Kajaki	110kV	1			0.5	m$
transformer Kajaki	110/20kV	1	25		0.5	m$
Subtotal G_02_A					1.1	m$

Table 8.2.11-7: CAPEX for network integration of Kajaki Expansion HPP up to 2015

The network configuration of Helmand province is given in **Annex 8.2.11-2**.

Stage B up to2020:
For network development in Stage B, the following installations are proposed:

(i) additional transformer 110/20 kV at Sangin North substation with a capacity of 16 MVA
(ii) additional transformer 110/20 kV at Lashkargah substation with a capacity of 16 MVA.

This will require a CAPEX of about $1.7. Network development up to 2020 is shown in **Annex 8.2.11-3**.

P_11_B					
Measure	Type	No	[MVA]	[km]	Cost
expansion subst. Sangin North	110kV	1			0.5 m$
transformer Sangin North	110/20kV	1	16		0.3 m$
expansion substation Lashkargah	110kV	1			0.5 m$
transformer Lashkargah	110/20kV	1	16		0.3 m$
Subtotal P_11_B					1.7 m$

Table 8.2.11-8: Additional CAPEX for power system in Helmand up to 2020

<u>Stage C up to 2025:</u>
For network development in Stage C, the

(i) erection of a new substation 110/20 kV at Musa Qala with a transformer capacity of 16 MVA and construction of a 110 kV line from Kajaki to Musa Qala with a length of about 37 km

is proposed. This will require a CAPEX of about $8.6m. The single-line diagram for this expansion Stage C is given in **Annex 8.2.11-4**.

P_11_C					
Measure	Type	No	[MVA]	[km]	Cost
expansion substation Kajaki	110kV	1			0.5 m$
new substation Musa Qala	110kV	2			3.3 m$
transformer Musa Qala	110/20kV	1	16		0.3 m$
110kV line Kajaki - Musa Qala	1x3x1xACSR185			37	4.4 m$
Subtotal P_11_C					8.6 m$

Table 8.2.11-9: Additional CAPEX for power system in Helmand up to 2025

<u>Stage D up to2032:</u>
In this period, no CAPEX for reinforcement of the transmission system is required in order to meet load growth.

The integration of Kajaki Addition HPP (GN_06) will require the following measures:
(i) installation of step-up transformer for new generation units at Kajaki and
(ii) construction of an additional 110 kV line from Kajaki to Durai Junction with a length of about 85 km.

CAPEX for network integration of Kajaki Addition HPP (GN_06) is estimated at $14.8m and the single-line diagram is given in **Annex 8.2.11-5**.

G_02_D	Additional CAPEX up to 2032				
Measure	Type	No	[MVA]	[km]	Cost
expansion substation Kajaki	110kV	4			2.2 m$
transformer Kajaki	110/20kV	4	30		2.5 m$
110kV line Kajaki - Durai Junction	1x3x1xACSR185			85	10.2 m$
Subtotal G_02_D					14.8 m$

Table 8.2.11-10: CAPEX for network integration of Kajaki Addition HPP up to 2032

8.2.12 Herat

8.2.12.1 Existing system

Herat is currently supplied by imports from Turkmenistan and Iran. The Turkmen - Herat line is routed from the north via Rubat Sangi to Noor Jahad substation. Noor Jahad substation is located north of Herat city. The loading of that line is dramatic and the voltage drop along the line is very high. The Turkmen import line is at the 220 kV level, although is currently operated at the 110 kV level

The Iran - Herat line approaches Herat from the west at Islam Qala and is routed via Ghirian to Mir Dawoud. Mir Dawoud substation is located in the south of Herat city. The voltage level of the Iran import line is 132 kV.

Existing load centers for Herat	Latitude N	Longitude E	
Ghorian	34°21'30"	61°29'	**
Mir Dawoud	34°11'2"	61°13'2"	*
Rubat Sangi	35°1'	62°12'	**
Noor Jahad	34°22'22.62	62°13'47.46"	*

* Substation found on map

** Substation coordinates estimated from map

Table 8.2.12-1: Existing load centers for Herat

For Herat, a high connection rate of 82% of households was reported for 2011 and the peak load was 133 MW.

Annex 8.2.12-1 shows the single-line diagram of the existing transmission system in Herat.

8.2.12.2 Network expansion

Demand in Herat will increase dramatically with a need for additional generation and import. Peak load for 2032 is expected at about 440 MW and the connection rate will reach 97.5%.

	Load and load forecast for Herat						
Year	2010	2011	2012	2015	2020	2025	2032
Population [thousand]	1710.1	1744.7					
No of households [thousand]	202.4	206.5	210.6	223.5	246.8	271.7	306.9
Connection rate [%]	62.7	82.4	83.7	87.5	91.5	94.0	97.5
Gross electricity demand [GWh]	588.9	834.4	888.4	1034.7	1315.9	1666.0	2302.5
Net electricity demand [GWh]	406.1	575.4	617.6	737.0	977.3	1270.8	1794.6
Peak demand [MW]	94.0	133.2	142.8	169.9	224.2	296.2	438.1

Table 8.2.12-2: Load and load forecast for Herat

The populated areas are along the River Harirud, which crosses Herat from east to west, and further load centers are expected to be supplied by new substations. The tentative locations of these substations are given in the following table.

Further load centers for Herat	Latitude N	Longitude E	
Karuh	34°29'10"	62°34'20"	*
Obe	34°20'40"	63°6'30"	*
Salma	34°19'50"	63°49'30"	*
Kohsan	34°38'	61°10'	*

* Substation coordinates estimated from map

Table 8.2.12-3: Further load centers for Herat

Most areas are already connected to the power supply system, but expansion and reinforcement of the transmission system will be necessary. Additional transformer capacity must be installed at the existing and new substation to meet load growth. Table 8.2.12-4 and Table 8.2.12-5 give the proposed capacities and expected loading of the transformers over the planning horizon.

	Existing and further transformer capacity [MVA] Herat						
		2011	**2012**	**2015**	**2020**	**2025**	**2032**
Ghorian	1 x 30	30.0	30.0	30.0	30.0	30.0	30.0
Ghorian	1 x 30						30.0
Mir Dawoud	2 x 30	60.0	60.0	60.0	60.0	60.0	60.0
Mir Dawoud	1 x 30					30.0	30.0
Mir Dawoud	1 x 30						30.0
Rubat Sangi	1 x 30	30.0	30.0	30.0	30.0	30.0	30.0
Noor Jahad	2 x 40	80.0	80.0	80.0	80.0	80.0	80.0
Noor Jahad	1 x 40					40.0	40.0
Noor Jahad	1 x 40						40.0
Karuh	1 x 16				16.0	16.0	16.0
Karuh	1 x 16						16.0
Obe	1 x 16				16.0	16.0	16.0
Obe	1 x 16						16.0
Salma	1 x 16			16.0	16.0	16.0	16.0
Salma	1 x 16						16.0
Kohsan	1 x 16					16.0	16.0
Kohsan	1 x 16						16.0
Total		200	200	216	248.0	334.0	498.0

Table 8.2.12-4: Existing and further transformer capacity [MVA] for Herat

	Existing and further load at substation level [MW] for Herat						
		2011	**2012**	**2015**	**2020**	**2025**	**2032**
Ghorian		20.0	21.4	23.6	27.1	26.6	26.4
Ghorian							26.4
Mir Dawoud		40.0	42.8	47.2	54.2	53.2	52.8
Mir Dawoud						26.6	26.4
Mir Dawoud							26.4
Rubat Sangi		20.0	21.4	23.6	27.1	26.6	26.4
Noor Jahad		53.3	57.1	62.9	72.3	71.0	70.4
Noor Jahad						35.5	35.2
Noor Jahad							35.2
Karuh					14.5	14.2	14.1
Karuh							14.1
Obe					14.5	14.2	14.1
Obe							14.1
Salma				12.6	14.5	14.2	14.1
Salma							14.1
Kohsan						14.2	14.1
Kohsan							14.1
Total		133.2	142.8	169.9	224.2	296.2	438.1

Table 8.2.12-5: Existing and further load at substation level [MW] for Herat

Furthermore, the integration of Herat province into the national grid of Afghanistan will be possible by construction of a transmission line from Faryab province down to Herat. Additional generation will be installed at Salma HPP.

8.2.12.3 Overview

Several measures are required in the staged development of the network in Herat province. The required total CAPEX on the transmission network to ensure power supply is estimated at $77.8m. For network integration of Salam HPP, a CAPEX of about $37m is estimated.

<u>Stage A up to 2015:</u>
The proposed initial measures for improving the power supply in Stage A are:

(i) erection of a 220 kV busbar at Noor Jahad with two interbus transformers 220/110 kV each with a capacity of 50 MVA
(ii) erection of a 220 kV busbar at Rubat Sangi with interbus transformer 220/110 kV with a capacity of 30 MVA
(iii) operation of the Turkmen import line at the 220 kV level.

These measures will require a CAPEX of about $18.3m.

P_12_A						
Measure	Type	No	[MVA]	[km]	Cost	
new substation Noor Jahad	220kV	4			6.5	m$
expansion subst. Noor Jahad	110kV	2			1.1	m$
transformer Noor Jahad	220/110kV	2	50		2.1	m$
new substation Rubat Sangi	220kV	4			7.0	m$
expansion subst. Rubat Sangi	110kV	2			1.1	m$
transformer Rubat Sangi	220/110kV	1	30		0.6	m$
Subtotal P_12_A					18.3	m$

Table 8.2.12-6: CAPEX for power system in Herat up to 2015

Furthermore, commissioning of the new hydropower plant at Salma is expected in the first stage. Network connection of Salma HPP will require:

(i) erection of 220 kV substation at Salam with step-up transformers 220/20 kV each with a capacity of 16 MVA for the generation units and construction of a 220 kV transmission line from Salma to Noor Jahad with a length of about 150 km.

It is assumed that the distribution network around Salma will be served from the power plant. CAPEX on network integration of Salma HPP (GN_01) is estimated at 36.6m$.

G_01_A	CAPEX up to 2015					
Measure	Type	No	[MVA]	[km]	Cost	
expansion subst. Noor Jahad	220kV	1			0.9	m$
new substation Salma	220kV	3			6.5	m$
transformer Salma	220/20kV	2	16		0.7	m$
220kV line Noor Jahad - Salma	1x3x1xACSR300			150	28.5	m$
Subtotal G_01_A					36.6	m$

Table 8.2.12-7: CAPEX for network integration of Salma HPP up to 2015

The single line diagram for development of the network in Herat up to 2015 is given in **Annex 8.2.12-2**.

Stage B up to 2020:

For the period from 2015 to 2020, the following measures are proposed:

(i) erection of substation 110/20 kV at Karuh with transformer 110/20 kV with a capacity of 16 MVA and transmission line 110 kV from Noor Jahad to Karuh with a length of about 36 km

(ii) erection of substation 220/20 kV at Obe with transformer 220/20 kV with a capacity of 16 MVA and loop-in of the transmission line from Noor Jahad to Salma.

The required CAPEX for implementing the measures for Stage B is estimated at $15.3m. **Annex 8.2.12-3** shows the single-line diagram for development up to 2020.

P_12_B						
Measure	Type	No	[MVA]	[km]	Cost	
expansion subst. Noor Jahad	110kV	1			0.5	m$
new substation Karuh	110kV	2			3.3	m$
transformer Karuh	110/20	1	16		0.3	m$
new substation Obe	220kV	3			6.5	m$
transformer Obe	220/20kV	1	16		0.3	m$
110kV line Noor Jahad - Karuh	1x3x1xACSR185			36	4.3	m$
Subtotal P_12_B					15.3	m$

Table 8.2.12-8: Additional CAPEX for power system in Herat up to 2020

<u>Stage C up to 2025:</u>
For development Stage C, it is proposed to add the following equipment to the transmission system of Herat:

(i) construction of 220 kV busbar at Mir Dawoud with two interbus transformers 220/132 kV with a capacity of 50 MVA each and construction of a 220 kV line Noor Jahad to Mir Dawoud with a length of about 50 km
(ii) installation of an additional transformer 132/20 kV at Mir Dawoud with a capacity of 30 MVA
(iii) installation of an additional interbus transformer 220/110 kV at Noor Jahad with a capacity of 40 MVA
(vi) installation of an additional transformer 110/20KV at Noor Jahad with a capacity of 40 MVA
(v) erection of new substation 132/20 kV at Kohsan with one transformer with a capacity of 16 MVA and loop-in of the existing line from Iran to Ghorian.

CAPEX for implementing the measures of Stage C is estimated at $28.8m.

P_12_C						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Noor Jahad	220kV	2			1.8	m$
expansion substation Noor Jahad	110kV	2			1.1	m$
transformer Noor Jahad	220/110kV	1	50		1.0	m$
transformer Noor Jahad	110/20kV	1	40		0.8	m$
new substation Mir Dawoud	220kV	3			6.5	m$
expansion substation Mir Dawoud	132kV	3			1.6	m$
transformer Mir Dawoud	220/132kV	2	50		2.1	m$
transformer Mir Dawoud	132/20kV	1	30		0.6	m$
new substation Kohsan	132kV	3			3.5	m$
transformer Kohsan	132/20kV	1	16		0.3	m$
220kV line Noor J. - Mir Dawoud	1x3x1xACSR300			50	9.5	m$
Subtotal P_12_C					28.8	m$

Table 8.2.12-9: Additional CAPEX for power system in Herat up to 2025

A major transmission project will be connection of the Herat region to the national grid of Afghanistan. Therefore, construction of the transmission line from Andkhoy to Herat at the 220 kV level is proposed. Construction of the Herat interconnection line from Qala-e Naw to

Noor Jahad, first circuit length about 110 km, was already discussed within the major transmission project T_05 in section 6.3.6.

Annex 8.2.12-4 shows network development for the Herat transmission system up to 2025.

Stage D up to 2032:
To meet expected load growth up to 2032, installation of additional transformer capacity at different substations is required.

(i) one additional transformer at Ghorian 132/20 kV with a capacity of 30 MVA
(ii) two additional interbus transformers 220/132 kV with a capacity of 50 MVA each and one additional transformer 132/20 kV with a capacity of 30 MVA at Mir Dawoud
(iii) one additional interbus transformer 220/110 kV with a capacity of 40 MVA and one additional transformer 110/20 kV with a capacity of 50 MVA at Noor Jahad
(vi) one additional transformer 110/20 kV with a capacity of 16 MVA at Karuh
(v) one additional transformer 220/20 kV with a capacity of 16 MVA at Obe
(iv) one additional transformer 132/20 kV with a capacity of 16 MVA at Kohsan.

These measures will require a CAPEX of about $15.3m.

P_12_D						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Ghorian	132kV	1			0.5	m$
transformer Ghorian	132/20kV	1	30		0.6	m$
expansion subst. Mir Dawoud	220kV	2			1.8	m$
expansion subst. Mir Dawoud	132kV	3			1.6	m$
transformer Mir Dawoud	220/132kV	2	50		2.1	m$
transformer Mir Dawoud	132/20kV	1	30		0.6	m$
expansion subst. Noor Jahad	220kV	1			0.9	m$
expansion subst. Noor Jahad	110kV	2			1.1	m$
transformer Noor Jahad	220/110kV	1	50		1.0	m$
transformer Noor Jahad	110/20kV	1	40		0.8	m$
expansion substation Karuh	110kV	2			1.1	m$
transformer Karuh	110/20kV	1	40		0.8	m$
expansion substation Obe	220kV	1			0.9	m$
transformer Obe	220/20kV	1	16		0.3	m$
expansion substation Kohsan	132kV	1			0.5	m$
transformer Kohsan	132/20kV	1	30		0.6	m$
Subtotal P_12_D					15.3	m$

Table 8.2.12-10: Additional CAPEX for power system in Herat up to 2032

For the period 2025 to 2032, it is further proposed to string the second circuit of the Andkhoy to Herat interconnector, which was already covered under the major transmission project T_05 in section 6.3.

The single-line diagram of the network expected for 2032 is given in **Annex 8.2.12-5**.

8.2.13 Jowzjan

8.2.13.1 Existing system

Jowzjan province currently has two 110 kV substations at Khawaja Doko and Sheberghan. Khawaja Doko with a transformer capacity of 2.5 MVA serves the region north of Sheberghan town. Sheberghan substation is located about 10 km south of Sheberghan town near the gas fields and, with a transformer capacity of 2x16 MVA, feeds a 35 kV distribution network for Sheberghan town.

The Jowzjan area is currently supplied via a 110 kV single-circuit line from Andkhoy to Sheberghan. The 110 kV line from Sheberghan substation to Mazar-e-Sharif is currently destroyed.

The existing system consists of the following substations at the 110 kV level.

Existing load centers for Jowzjan	Latitude N	Longitude E	
Sheberghan	36°33'18.5"	67° 8'46.3"	*
Khawaja Doko	36°49'30"	65°36'50"	**

* Substation coordinates given by DABS (DBS_026)

** Substation coordinates estimated from map

Table 8.2.13-1: Existing load centers for Jowzjan

Annex 8.2.13-1 shows the single-line diagram for the existing system in Jowzjan province.

Due to high loading of the long import line at the 110 kV level from Turkmenistan to Andkhoy, as already described in section 8.2.8, the voltage level at Sheberghan substation is dramatically low during peak load times and only a proportion of about 56% of current electricity demand can be met. Improving the voltage level in this region is a precondition for making an increase in load possible. Reinforcement is required even to supply the existing connected load network.

8.2.13.2 Network expansion

Upon introduction of the 220 kV level for the new infeed from Turkmenistan in the first phase of the TKM-AFG interconnection project, the power supply from Sheberghan substation at the 220 kV level will present an opportunity to serve the currently connected loads as well as the expected additional loads according to the load forecast for Jowzjan province, as shown in the following table:

Year	Load and load forecast for Jowzjan 2010	2011	2012	2015	2020	2025	2032
Population [Thousand]	494.2	503.1					
No of Households [Thousand]	56.3	57.5	58.6	62.2	68.7	75.6	85.4
Connection rate [%]	40.5	42.6	47.2	60.9	73.0	78.0	82.5
Gross Electricity Demand [GWh]	51.9	51.5	60.0	90.0	139.7	180.5	254.1
Net Electricity Demand [GWh]	35.8	35.5	41.7	64.1	103.8	137.7	198.0
Peak Demand [MW]	10.8	10.7	12.5	18.7	29.0	37.5	48.3

Table 8.2.13-2: Load and load forecast for Jowzjan

Reinforcement of the connection between Sheberghan and Mazar-e-Sharif is also a focus of the TKM-AFG interconnection project. This connection will be at the 220 kV level and will mostly follow the route of the destroyed 110 kV line. This line will pass the load center of Aqcha and will present an opportunity to connect it via a 220 kV t-off from the new line. The following table gives the tentative location of the new substation to be erected in Aqcha.

Further load centers for Jowzjan	Latitude N	Longitude E	
Aqcha	36°54'53"	66°10'54"	*

* Substation coordinates estimated from map

Table 8.2.13-3: Further load centers for Jowzjan

For Aqcha substation, a first step-down transformer with a capacity of 10 MVA is expected in 2015, with a second being added in 2020.

		Existing and further transformer capacity [MVA] Jowzjan 2011	2012	2015	2020	2025	2032
Sheberghan	2 x 16	32.0	32.0	32.0	32.0	32.0	32.0
Khawaja Doko	1 x 2.5	2.5	2.5	2.5	2.5	2.5	2.5
Aqcha	1 x 10			10.0	10.0	10.0	10.0
Aqcha	1 x 10				10.0	10.0	10.0
Total		34.5	34.5	44.5	54.5	54.5	54.5

Table 8.2.13-4: Existing and further transformer capacity [MVA] for Jowzjan

A comparison of the expected load growth by substation with the capacity of the step-down transformer at the substation is presented in Table 8.2.13-5. Table 8.2.13-4 above shows that, from 2032 onwards, additional transformer capacity will be required. The transformer capacity will be sufficient for the planning horizon.

		Existing and further load at substation level [MW] for Jowzjan 2011	2012	2015	2020	2025	2032
Sheberghan		9.9	11.6	13.4	17.0	22.0	28.4
Khawaja Doko		0.8	0.9	1.0	1.3	1.7	2.2
Aqcha				4.2	5.3	6.9	8.9
Aqcha					5.3	6.9	8.9
Total		10.7	12.5	18.7	29.0	37.5	48.3

Table 8.2.13-5: Existing and further load at substation level [MW] for Jowzjan

8.2.13.3 Overview

To meet load growth, staged development in Jowzjan province is proposed as follows, with total CAPEX for network development for supply of the loads being estimated at $12.1m. The major project of the new Turkmenistan to Afghanistan interconnector was discussed in section 6.3. Furthermore, network integration of Sheberghan thermal power plant is proposed and the CAPEX for this network integration is estimated at $17m.

<u>Stage A up to 2015:</u>
For stage A, it is proposed to:

(i) erect a new substation 110/20 kV at Aqcha with transformer capacity of 10 MVA with tie-in line from the new line Mazar-e-Sharif to Sheberghan with a length of about 25 km.

CAPEX for Stage A measures are estimated at 11 and the single-line diagram for Stage A development is given in **Annex 8.2.13-2**, which also shows the development of the TKM-AFG interconnector.

P_13_A Measure	Type	No	[MVA]	[km]	Cost	
new substation Aqcha	220kV	2			6.0	m$
transformer Aqcha	220/20kV	1	10		0.2	m$
220kV line Tie In - Aqcha	1x3x1xACSR300			25	4.8	m$
Subtotal P_13_A					11.0	m$

Table 8.2.13-6: CAPEX for power system in Jowzjan up to 2015

<u>Stage B up to 2020:</u>
For Stage B, it is proposed to install an

(i) additional transformer 220/20 kV at Aqcha with a capacity of 10 MVA.

The required CAPEX will be about $1.1m and the single-line diagram for Stage B development is shown in **Annex 8.2.13-3**.

P_13_B Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Aqcha	220kV	1			0.9	m$
transformer Aqcha	220/20kV	1	10		0.2	m$
Subtotal P_13_B					1.1	m$

Table 8.2.13-7: Additional CAPEX for power system in Jowzjan up to 2020

Besides network development for power supply, expansion for integration of the first four units of Sheberghan thermal power plant into the network is expected. CAPEX for a

(i) step-up transformer 220/20 kV at Sheberghan each with a capacity of 60 MVA

is estimated at $8.5m (GN_21_B).

G_21_B	Additional CAPEX up to 2020					
Measure	Type	No	[MVA]	[km]	Cost	
expansion subst. Sheberghan	220kV	4			3.6	m$
transformer Sheberghan	220/20kV	4	60		4.9	m$
Subtotal G_21_B					8.5	m$

Table 8.2.13-8: CAPEX for network integration of Sheberghan TPP up to 2020

<u>Stage C up to 2025:</u>
For the period 2020 to 2025, no CAPEX is required to meet load growth.

For integration of the second four units of Sheberghan TPP, CAPEX for a

(i) step-up transformer 220/20 kV at Sheberghan each with a capacity of 60 MVA

is estimated at $8.5m (GN_21_C).

G_21_C	Additional CAPEX up to 2025					
Measure	Type	No	[MVA]	[km]	Cost	
expansion subst. Sheberghan	220kV	4			3.6	m$
transformer Sheberghan	220/20kV	4	60		4.9	m$
Subtotal G_21_C					8.5	m$

Table 8.2.13-9: CAPEX for network integration of Sheberghan TPP up to 2025

<u>Stage D up to 2032:</u>
For the period 2025 to 2032, no CAPEX is required.

8.2.14 Kabul

8.2.14.1 Existing system

Kabul has a 110 kV network with a feed-in from the Pul-e-Chomri lines and the several generation units in the Kabul region. The locations of the existing substations and power plants are given in Table 8.2.14-1.

Existing load centers for Kabul	Latitude N	Longitude E	
Chimtala	34°36'47.62"	69° 5'6.90"	*
Kabul North West	34°33'54.83"	69° 6'46.78"	**
Kabul North	34°34'1.16"	69° 9'33.77"	**
Kabul East	34°32'20.17"	69°15'45.50"	**
Breshna Kot (Kabul Town)	34°29'42.89"	69° 9'56.60"	**
Botkhak	34°29'58.37"	69°20'58.50"	***
Pul-e-Charkhi	34°32'28.94"	69°21'16.05"	**
Sarobi Town	34°37'54.49"	69°43'9.11"	***
Existing Power Plants	**Latitude N**	**Longitude E**	
Tarakhil	34°33'42.26"	69°17'40.73"	**
Mahipar	34°33'21.07"	69°28'43.47"	**
Naglu	34°38'27.48"	69°43'1.01"	**
Sarobi	34°35'10.41"	69°46'34.04"	***
Darunta	34°29'4.73"	70°21'47.48"	***

* Substation coordinates given by DABS (DBS_026)
** Substation coordinates taken from map
*** Substation coordinates estimated from map

Table 8.2.14-1: Existing load and generation centers for Kabul

The current connection rate for households in Kabul was reported at about 45% in 2011. The existing transmission system in Kabul is given in **Annex 8.2.14-1**.

8.2.14.2 Network expansion

According to the load forecast, peak demand in Kabul will increase to above 1200 MW in 2032 and the expected connection rate will reach almost 100%. The load forecast for Kabul is given in the following table.

	Load and load forecast for Kabul						
Year	**2010**	**2011**	**2012**	**2015**	**2020**	**2025**	**2032**
Population [thousand]	3691.4	3818.7					
No of Households [Thousand]	573.9	591.1	608.9	661.4	744.7	819.8	926.3
Connection rate [%]	43.9	44.4	52.0	74.8	91.5	94.0	97.5
Gross electricity demand [GWh]	1219.3	1701.8	1907.2	2564.1	3606.0	4605.8	6389.6
Net electricity demand [GWh]	851.5	1173.6	1330.4	1832.8	2688.0	3526.7	4999.7
Peak demand [MW]	248.1	402.0	441.4	559.4	718.1	876.3	1215.7

Table 8.2.14-2: Load and load forecast for Kabul

A key network expansion in Kabul province will be extra feed-in from an additional line crossing the Hindu Kush to the new Arghandi substation located south of Kabul. The planned expansion of the city towards the north following the Kabul New City project is taken into consideration with two new substations connected to the 220 kV network. Table 8.2.14-3 gives the locations of the further load centers in Kabul.

Further load centers for Kabul	Latitude N	Longitude E	
Bagram	34°51'51.32"	69°16'39.18"	*
New Kabul City	34°38'1.53"	69°17'0.51"	*
Arghandi	34°28'25.45"	68°56'57.87"	**

* Substation coordinates estimated according to KNC project

** According to Information from DABS (DABS_030)

Table 8.2.14-3: Further load centers for Kabul

Expected high load growth in Kabul requires the installation of additional transformer capacity at the existing and new substations. The proposal for allocation of transformer capacity and expected loading of the transformers is given in Table 8.2.14-4 and Table 8.2.14-5.

	Existing and further transformer capacity [MVA] Kabul						
		2011	**2012**	**2015**	**2020**	**2025**	**2032**
Chimtala	2 x 40	80.0	80.0	80.0	80.0	80.0	80.0
Chimtala	2 x 40						80.0
Kabul North West	2 x 25	50.0	50.0	50.0	50.0	50.0	50.0
Kabul North West	1 x 20	20.0	20.0	20.0	20.0	20.0	20.0
Kabul North West	2 x 40	80.0	80.0	80.0	80.0	80.0	80.0
Kabul North West	1 x 50						50.0
Kabul North	4 x 40	160.0	160.0	160.0	160.0	160.0	160.0
Kabul North	1 x 40						40.0
Kabul East	1 x 25	25.0	25.0	25.0	25.0	25.0	
Kabul East	1 x 40						40.0
Kabul East	1 x 40	40.0	40.0	40.0	40.0	40.0	40.0
Breshna Kot (Kabul Town)	2 x 25	50.0	50.0	50.0	50.0	50.0	50.0
Botkhak	2 x 40	80.0	80.0	80.0	80.0	80.0	80.0
Botkhak	1 x 20						20.0
Pul-e-Charkhi	2 x 6.3	12.6	12.6	12.6	12.6	12.6	12.6
Sarobi Town	1 x 5.6	5.6	5.6				
Sarobi Town	1 x 32			32.0	32.0	32.0	32.0
Sarobi Town	1 x 32						32.0
Bagram	2 x 40			80.0	80.0	80.0	80.0
Bagram	1 x 40				40.0	40.0	40.0
Bagram	2 x 40					80.0	80.0
Dehsabz South	2 x 40			80.0	80.0	80.0	80.0
Paymonar	1 x 40				40.0	40.0	40.0
Dehsabz North	2 x 40					80.0	80.0
Arghandi	1 x 25			25.0	25.0	25.0	25.0
Total		603.2	603.2	814.6	894.6	1054.6	1291.6

Table 8.2.14-4: Existing and further transformer capacity [MVA] for Kabul

	Existing and further load at substation level [MW] for Kabul						
		2011	2012	2015	2020	2025	2032
Chimtala		53.3	58.5	54.9	64.2	66.5	75.3
Chimtala							75.3
Kabul North West		33.3	36.6	34.3	40.1	41.5	47.1
Kabul North West		13.3	14.6	13.7	16.1	16.6	18.8
Kabul North West		53.3	58.5	54.9	64.2	66.5	75.3
Kabul North West							47.1
Kabul North		106.6	117.1	109.9	128.4	132.9	150.6
Kabul North							37.6
Kabul East		16.7	18.3	17.2	20.1	20.8	
Kabul East							37.6
Kabul East		26.7	29.3	27.5	32.1	33.2	37.6
Breshna Kot (Kabul Town)		33.3	36.6	34.3	40.1	41.5	47.1
Botkhak		53.3	58.5	54.9	64.2	66.5	75.3
Botkhak							18.8
Pul-e-Charkhi		8.4	9.2	8.7	10.1	10.5	11.9
Sarobi Town		3.7	4.1				
Sarobi Town				22.0	25.7	26.6	30.1
Sarobi Town							30.1
Bagram				54.9	64.2	66.5	75.3
Bagram					32.1	33.2	37.6
Bagram						66.5	75.3
Dehsabz South				54.9	64.2	66.5	75.3
Paymonar					32.1	33.2	37.6
Dehsabz North						66.5	75.3
Arghandi				17.2	20.1	20.8	23.5
Total		402.0	441.4	559.4	718.1	876.3	1215.7

Table 8.2.14-5: Existing and further load at substation level [MW] for Kabul

8.2.14.3 Overview

Development of the transmission network in Kabul is expected to follow the below-described stages. The expected CAPEX on Kabul transmission network expansion for power supply (P_14) will add up to about $135.3m and CAPEX on the major transmission project for the transmission line to the Pakistan border (T_04) is discussed in chapter 6.3.

<u>Stage A up to 2015:</u>
For the first stage,

(i) erection of new substation 220/20 kV at Bagram with two transformers 40 MVA and 220 kV transmission line Charikar to Bagram with a length of about 20 km
(ii) erection of new substation 220/20 kV at Dehsabz South with two transformers 220/20 kV 40MVA each and 220 kV double circuit line Chimtala to Dehsabz South with a length of about 20 km
(iii) erection of new substation 220/110/20 kV at Arghandi south of Kabul with interbus transformer 220/110 kV 160 MVA and transformer 110/20 kV with a capacity of

25 MVA and 220 kV double-circuit line from Chimtala to Arghandi with a length of about 23 km

(vi) construction of two 110 kV lines from Arghandi to Breshna Kot with a length of about 12 km

(v) change of transformer at Sarobi Town with a capacity of 32 MVA

will create additional infeed points for Kabul. CAPEX for Stage A is estimated at $60.3m, as given in Table 8.2.14-6 and the resulting network configuration is shown in **Annex 8.2.14-2**.

P_14_A Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Charikar	220kV	1			0.9	$m
new substation Bagram	220kV	3			6.5	$m
transformer Bagram	220/20kV	2	40		1.6	$m
expansion substation Chimtala	220kV	2			1.8	$m
new substation Dehsabz South	220kV	4			7.0	$m
transformer Dehsabz South	220/20kV	2	40		1.6	$m
expansion substation Chimtala	220kV	2			1.8	$m
expansion subst. Breshna Kot	110kV	2			1.1	$m
new substation Arghandi	220kV	3			6.5	$m
new substation Arghandi	110kV	4			3.7	$m
interbus transformer Arghandi	220/110kV	1	160		3.3	$m
transformer Arghandi	110/20kV	1	25		0.5	$m
transformer Sarobi Town	110/20kV	1	32		0.7	$m
220kV line Charikar - Bagram	1x3x1xACSR300			20	3.8	$m
220kV line Chimtala - Dehsabz S.	2x3x1xACSR300			20	5.8	$m
220kV line Chimtala - Arghandi	2x3x2xACSR300			23	11.5	$m
110kV line Arghandi - Breshna K.	2x3x1xACSR185			12	2.2	$m
Subtotal P_14_A					60.3	$m

Table 8.2.14-6: CAPEX for power system in Kabul up to 2015

Stage B up to 2020:
For 2020, it is expected that the additional line crossing the Hindu Kush will reach Argandi substation. The 500 kV substation at Arghandi and the two 500/220 kV interbus transformers are discussed under the major transmission project T_02 in section 6.3.

For the transmission network of Kabul in Stage B, the

(i) installation of an additional transformer at Bagram with capacity 40 MVA

(ii) Construction of substation Paymonar 220/20 kV within Kabul New City project with transformer 220/20 kV with capacity 40 MVA, loop in of the double circuit line from Chimtala to Dehsabz South

(iii) power supply of expected Aynak Copper Mine (100 MW in the first stage) due to erection of 220/20 kV substation at Aynak with 220/20 kV transformer 3x40 MVA and construction of 220 kV line Arghandi to Aynak Copper Mine of length of about 40 km

are required. The estimated CAPEX for transmission network development in Stage B is $27m and the single-line diagram is given in **Annex 8.3.14-3**.

P_14_B						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Bagram	220kV	1			0.9	$m
transformer Bagram	220/20kV	1	40		0.8	$m
new substation Paymonar	220kV	5			7.4	$m
transformer Paymonar	220/20kV	1	40		0.8	$m
new substation Aynak	220kV	4			7.0	$m
transformer Aynak	220/20kV	3	40		2.5	$m
220kV line Arghandi - Aynak	1x3x1xACSR300			40	7.6	$m
Subtotal P_14_B					27.0	$m

Table 8.2.14-7: Additional CAPEX for power system in Kabul up to 2020

<u>Stage C up to 2025:</u>

For development between 2020 and 2025 in Kabul, the following expansions are expected:

(i) two additional transformers 220/20 kV at Bagram 40 MVA each
(ii) two additional transformers 110/20 kV at Paymonar 40 MVA each for supply of Dehsabz North
(iii) additional transformer 220/20 kV at Aynak to serve additional load for second stage of copper mine
(vi) new substation 220 kV at Naglu with interbus transformer 160 MVA
(v) construction of 220 kV line from Naglu to Aybak, length of about 45 km and 220 kV line from Naglu to Kapisa, of length about 40 km.

The line will be routed along the site of further HPP Baghdara and will close the 220 kV ring around Kabul.

The CAPEX required for expansion Stage C is estimated at about $39.4m, as shown in Table 8.2.14-8. The resulting single-line diagram showing the Kabul transmission network expected for 2025 is given in Annex 8.2.14-4.

P_14_C						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Bagram	220kV	2			1.8	$m
transformer Bagram	220/20kV	2	40		1.6	$m
expansion subst. Paymonar	220kV	2			1.8	$m
transformer Dehsabz North	220/20kV	2	40		1.6	$m
expansion substation Aynak	220kV	4			3.6	$m
transformer Aynak	220/20kV	3	40		2.5	$m
new substation Naghlu	220kV	3			6.5	$m
expansion substation Naghlu	110kV	1			0.5	$m
interbus transformer Naghlu	220/110kV	1	160		3.3	$m
220kV line Naghlu - Aynak	1x3x1xACSR300			45	8.6	$m
220kV line Naghlu - Kapisa	1x3x1xACSR300			40	7.6	$m
Subtotal P_14_C					39.4	$m

Table 8.2.14-8: Additional CAPEX for power system in Kabul up to 2025

Stage D up to 2032:

Due to demand growth, it is expected that additional transformer capacity will be needed at several substations in Kabul as follows:

(i) additional two transformers 110/20 kV at Chimtala each with a capacity of 40 MVA
(ii) additional transformer 110/20 kV at Kabul North West with a capacity of 50MVA
(iii) additional transformer 110/20 kV at Kabul North with a capacity of 40 MVA
(vi) replacement of transformer 110/20 kV 25 MVA at Kabul East with a capacity of 40 MVA
(v) additional transformer 110/20 kV at Botkhak with a capacity of 20 MVA
(iv) additional transformer 110/20 kV at Sarobi Town with a capacity of 32 MVA.

The CAPEX required for this reinforcement of the transmission system is estimated at $8.6m.

P_14_D Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Chimtala	110kV	2			1.1	m$
transformer Chimtala	110/20kV	2	40		1.6	m$
expansion subst. Kabul North W.	110kV	1			0.5	m$
transformer Kabul North West	110/20kV	1	50		1.0	m$
expansion subst Kabul North	110kV	1			0.5	m$
transformer Kabul North	110/20kV	1	40		0.8	m$
transformer Kabul East	110/20kV	1	40		0.8	m$
expansion substation Botkhak	110kV	1			0.5	m$
transformer Botkhak	110/20kV	1	20		0.4	m$
expansion subst. Sarobi Town	110kV	1			0.5	m$
transformer Sarobi Town	110/20kV	1	32		0.7	m$
Subtotal P_14_D					8.6	m$

Table 8.2.14-9: Additional CAPEX for power system in Kabul up to 2032

The network configuration for Kabul in 2032 is given in **Annex 8.2.14-5**. Construction of the Pakistan interconnection will be possible also earlier in line with construction of the new Hindu Kush crossing with a 500 kV line.

8.2.15 Kandahar

8.2.15.1 Existing system

The existing system in Kandahar operates at the 20 kV and 110 kV levels and is connected to the system in Helmand. The system is fed by four sets of diesel generator units in Kandahar connected to the 20 kV distribution system and by Kajakai hydropower plant, which is connected to the 110 kV transmission system. The study is focused on the transmission system and, therefore, the existing load and the existing generation unit are considered as connected directly to the 20 kV busbar of the 110/20 kV substation in Kandahar.

The exact location of the substation in Kandahar is not known by the consultant. The location is assumed as follows:

Existing load centers for Kandahar	Latitude N	Longitude E	
Kandahar	31°37'	65°43'	*

* Detailed location of substation is not known

Table 8.2.15-1: Existing load centers for Kandahar

The existing transformer capacity at Kandahar substation is 25 MVA. This will not be sufficient in case the loads are supplied without local generation with the diesel sets. After construction of the NEPS to SEPS interconnector, additional capacity of the step-down transformer will be necessary.

The single-line diagram of the existing system in Kandahar is given in **Annex 8.2.15-1**. Currently, the connection rate is reported as 35% with the peak load reaching 35 MW.

8.2.15.2 Network expansion

Demand in Kandahar will increase to 165 MW in the planning horizon and the connection rate will come to 92.5% according to the demand forecast shown in Table 8.2.15-2 below.

	Load and load forecast for Kandahar						
Year	**2010**	**2011**	**2012**	**2015**	**2020**	**2025**	**2032**
Population [Thousand]	1103.4	1127.0					
No of Households [Thousand]	135.3	138.0	140.8	149.4	164.9	181.5	205.1
Connection rate [%]	29.7	34.8	42.3	64.9	83.0	88.0	92.5
Gross Electricity Demand [GWh]	99.6	167.6	201.0	307.1	458.7	607.5	871.4
Net Electricity Demand [GWh]	68.7	115.6	139.7	218.7	340.7	463.4	679.2
Peak Demand [MW]	20.7	34.8	41.7	63.7	95.2	126.1	165.8

Table 8.2.15-2: Load and load forecast for Kandahar

The load center in Kandahar province is Kandahar city, the capital of the province. Further load is expected along the ring road at Maiwand.

Further load centers for Kandahar	Latitude N	Longitude E	
Maiwand	31°37'	65° 4'30"	*

* Substation coordinates estimated from map

Table 8.2.15-3: Further load centers for Kandahar

The expected high growth in demand will require the installation of additional transformer capacity at the existing and new substations in Kandahar. The required capacity and the expected loading of the transformers are given in the following tables.

		Existing and further transformer capacity [MVA] Kandahar					
		2011	2012	2015	2020	2025	2032
Kandahar	1 x 25	25.0	25.0	25.0	25.0	25.0	25.0
Kandahar	1 x 25			25.0	25.0	25.0	25.0
Kandahar	1 x 50				50.0	50.0	50.0
Kandahar	1 x 50						50.0
Maiwand	1 x 16			16.0	16.0	16.0	16.0
Maiwand	1 x 16					16.0	16.0
Maiwand	1 x 16						16.0
Total		25	25	66	116	132	198

Table 8.2.15-4: Existing and further transformer capacity [MVA] for Kandahar

		Existing and further load at substation level [MW] for Kandahar					
		2011	2012	2015	2020	2025	2032
Kandahar		34.8	41.7	24.1	20.5	23.9	20.9
Kandahar				24.1	20.5	23.9	20.9
Kandahar					41.0	47.8	41.9
Kandahar							41.9
Maiwand				15.5	13.1	15.3	13.4
Maiwand						15.3	13.4
Maiwand							13.4
Total		34.8	41.7	63.7	95.2	126.1	165.8

Table 8.2.15-5: Existing and further load at substation level [MW] for Kandahar

Routing of the interconnector to Kandahar will require expansion of the existing 110/20 kV substation with 220 kV busbar and interbus transformer.

8.2.15.3 Overview

In Kandahar, the following staged development of the transmission system will be necessary in the planning horizon. Total CAPEX will be about $14.2m.

In the period 2015 to 2020, it is expected that the NEPS to SEPS interconnector will be routed as far as Kandahar. The major interconnection project was already discussed in section 6.3 and CAPEX on the line and the 220 kV substation with interbus transformers 220/110 kV 2 x 50 MVA and expansion of the 110 kV busbar will be covered in the interconnection project.

Stage A up to 2015:
In the first stage

(i) erection of an additional substation 110/20 kV at Maiwand with transformer capacity of 16 MVA and loop-in to the existing 110 kV line from Kandahar to Durai Junction
(ii) additional transformer 110/20 kV with a capacity of 25 MVA at Kandahar
is proposed. Capital expenditure in Stage A will be about $4.9m and the resulting transmission network is shown in **Annex 8.2.15-2**.

P_15_A Measure	Type	No	[MVA]	[km]	Cost	
new substation Maiwand	110kV	3			3.5	m$
transformer Maiwand	110/20kV	1	16		0.3	m$
expansion substation Kandahar	110kV	1			0.5	m$
transformer Kandahar	110/20kV	1	25		0.5	m$
Subtotal P_15_A					4.9	m$

Table 8.2.15-6: CAPEX for power system in Kandahar up to 2015

Stage B up to 2020:
For transmission system development in Kandahar in Stage B, the

(i) installation of an additional transformer 110/ 20 kV at Kandahar substation 50 MVA

will be necessary to meet load growth. The required CAPEX is estimated at $1.6m. See **Annex 8.2.15-3** for the single-line diagram of the resulting network up to 2020.

P_15_B Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Kandahar	110kV	1			0.5	m$
transformer Kandahar	110/20	1	50		1.0	m$
Subtotal P_15_B					1.6	m$

Table 8.2.15-7: Additional CAPEX for power system in Kandahar up to 2020

Stage C up to 2025:
To meet load growth up to 2025, an

(i) additional interbus transformer 220/110 kV at Kandahar with a capacity of 50 MVA
(ii) additional transformer 110/20 kV at Maiwand substation with a capacity of 16 MVA

will be required. Capital expenditure is estimated at $3.3m and the resulting network is shown in **Annex 8.2.15-4**.

P_15_C						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Kandahar	220kV	1			0.9	m$
expansion substation Kandahar	110kV	1			0.5	m$
transformer Kandahar	220/110kV	1	50		1.0	m$
expansion substation Maiwand	110kV	1			0.5	m$
transformer Maiwand	110/20	1	16		0.3	m$
Subtotal P_15_C					3.3	m$

Table 8.2.15-8: Additional CAPEX for power system in Kandahar up to 2025

Stage D up to 2032:
To meet load growth up to 2032, an

(i) additional interbus transformer 220/110 kV with a capacity of 50 MVA and additional transformer 110/20 kV with a capacity of 50 MVA at Kandahar
(ii) additional transformer 110/20kV at Maiwand substation with a capacity of 16 MVA

will be required. Capital expenditure is estimated at $4.4m and the resulting network is shown in **Annex 8.2.15-5**.

P_15_D						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Kandahar	220kV	1			0.9	m$
expansion substation Kandahar	110kV	2			1.1	m$
transformer Kandahar	220/110kV	1	50		1.0	m$
transformer Kandahar	110/20kV	1	50		0.5	m$
expansion substation Maiwand	110kV	1			0.5	m$
transformer Maiwand	110/20	1	16		0.3	m$
Subtotal P_15_D					4.4	m$

Table 8.2.15-9: Additional CAPEX for power system in Kandahar up to 2032

8.2.16 Kapisa

8.2.16.1 Existing system

Kapisa province is located to the northeast of Kabul along the inflow of Naglu reservoir. Currently, Kapisa province has no connection to the Afghan national grid and the connection rate of households in Kapisa province was reported as zero for 2011.

8.2.16.2 Network expansion

Starting from an electrification rate of zero, it is expected that, in 2032, the connection rate will reach 65% and peak demand will be 27.5 MW. Details of the demand forecast are given in Table 8.2.16-1 below.

	Load and load forecast for Kapisa						
Year	**2010**	**2011**	**2012**	**2015**	**2020**	**2025**	**2032**
Population [Thousand]	406.2	413.0					
No of Households [Thousand]	40.7	41.4	42.2	44.8	49.5	54.5	61.5
Connection rate [%]	0.0	0.0	0.0	10.0	35.0	53.3	65.0
Gross Electricity Demand [GWh]	0.0	0.0	0.0	2.2	28.6	74.9	144.7
Net Electricity Demand [GWh]	0.0	0.0	0.0	1.6	21.2	57.1	112.8
Peak Demand [MW]	0.0	0.0	0.0	0.5	5.9	15.5	27.5

Table 8.2.16-1: Load and load forecast for Kapisa

The expected load centers are the capital of the province, Kapisa, and the Golbahar region in the valley near the road from Kabul to Salang Pass. Both of the new substations are close to the route of future lines for evacuating power from new hydropower plants in Golbahar and Baghdara. Therefore, connection of the new substations to Charikar and Bagram will be in the form of 220 kV lines.

The tentative locations for the new substations as listed below were taken from the map.

Further load centers for Kapisa	Latitude N	Longitude E	
Kapisa	34°57'45"N	69°34'45"E	*
Gulbahar	35° 8'30"N	69°18'E	*

* Substation coordinates estimated from map

Table 8.2.16-2: Further load centers for Kapisa

Table 8.2.16-3 and Table 8.2.16-4 show the transformer capacity and loading for the transformer to be installed at the substations in Kabisa and Golbahar.

	Existing and further transformer capacity [MVA] Kapisa						
		2011	2012	2015	2020	2025	2032
Kapisa	1 x 10				10.0	10.0	10.0
Kapisa	1 x 10					10.0	10.0
Gulbahar	1 x 10				10.0	10.0	10.0
Gulbahar	1 x 10					10.0	10.0
Total		0	0	0	20	40	40

Table 8.2.16-3: Existing and further transformer capacity [MVA] for Kapisa

	Existing and further load at substation level [MW] for Kapisa						
		2011	2012	2015	2020	2025	2032
Kapisa					3.0	3.9	6.9
Kapisa						3.9	6.9
Gulbahar					3.0	3.9	6.9
Gulbahar						3.9	6.9
Total		0.0	0.0	0.0	5.9	15.5	27.5

Table 8.2.16-4: Existing and further load at substation level [MW] for Kapisa

8.2.16.3 Overview

The staged development of the transmission network for Kapisa province (T_16) is presented in the following. The total CAPEX required for the transmission network is estimated at about $25.9m. The integration of a new power plant at Baghdara (GN_03) is estimated at about $14.8m.

Stage A up to 2015:
Power supply and network development will be possible starting from Charikar and Bagram after commissioning of these new substations.

Therefore, for the period up to 2015, no network expansion is planned for Kapisa province.

Stage B up to 2020:
To serve the new load centers in Kapisa,

(i) erection of new substation 220/20 kV at Gulbahar with transformer capacity 10 MVA and 220 kV transmission line from Chaikar to Gulbahar with a length of about 20 km
(ii) erection of new substation at Kapisa with transformer capacity of 10 MVA and 220 kV line from Bagram to Kapisa with a length of 30 km

are recommended.

Capital expenditure for Stage B is estimated at about $23.7m, as given in Table 8.2.16-5 below.

P_16_B					
Measure	Type	No	[MVA]	[km]	Cost
expansion substation Charikar	220kV	1			0.9 m$
new substation Gulbahar	220kV	2			6.0 m$
transformer Gulbahar	220/20kV	1	10		0.2 m$
expansion substation Bagram	220kV	1			0.9 m$
new substation Kapisa	220kV	2			6.0 m$
transformer Kapisa	220/20kV	1	10		0.2 m$
220kV line Charikar - Gulbahar	1x3x1xACSR300			20	3.8 m$
220kV line Charikar - Gulbahar	1x3x1xACSR300			30	5.7 m$
Subtotal P_16_B					23.7 m$

Table 8.2.16-5: Additional CAPEX for power system in Kapisa up to 2020

The single-line diagram in **Annex 8.2.16-3** shows the network configuration for Stage B, including the measures required for connecting Panjshir province, which are discussed in section 8.2.27.

<u>Stage C up to 2025:</u>
To meet the increase in demand up to 2025, installation of

(i) additional transformer 220/20 kV 10 MVA at Gulbahar
(ii) additional transformer 220/20 kV 10 MVA at Kapisa

are required.

Capital expenditure for Stage C will add up to $2.2m.

P_16_C					
Measure	Type	No	[MVA]	[km]	Cost
expansion substation Gulbahar	220kV	1			0.9 m$
transformer Gulbahar	220/20kV	1	10		0.2 m$
expansion substation Kapisa	220kV	1			0.9 m$
transformer Kapisa	220/20kV	1	10		0.2 m$
Subtotal P_16_C					2.2 m$

Table 8.2.16-6: Additional CAPEX for power system in Kapisa up to 2025

The single-line diagram shown in Annex 8.2.16-4 comprises the network development for Kapisa province up to 2025 and also includes the additional line from Kapisa substation to Naglu. This line is covered in the network development for Kabul discussed in section 8.2.14.

<u>Stage D up to 2032:</u>
Stage D will require no additional CAPEX on the transmission network to meet the growth in demand in Kapisa province.

If Baghdara hydropower plant is constructed, network integration for that project will be necessary in Stage D. The power plant will be looped into the 220 kV line from Kapisa to Naglu. Capital expenditure on these installations is estimated at about $14.8m.

G_03_D	Additional CAPEX up to 2032					
Measure	Type	No	[MVA]	[km]	Cost	
new substation Baghdara	220kV	8			8.6	m$
transformer Baghdara	220/20kV	6	50		6.2	m$
Subtotal G_03_D					14.8	m$

Table 8.2.16-7: CAPEX for network integration of Baghdara HPP up to 2032

The configuration of the transmission network in Kapisa province, including the possible HPP at Baghdara, is shown in **Annex 8.2.16-5**. The expansion for network integration of Gulbahar HPP is also shown. Integration itself is covered in section 8.2.27.

8.2.17 Khost

8.2.17.1 Existing system

Khost province is located at the border to Pakistan and is currently not connected to the national grid of Afghanistan.

8.2.17.2 Network expansion

According to the demand forecast, the peak load in Khost will increase to 46 MW and the connection rate will reach 70% in 2032.

	Load and load forecast for Khost						
Year	**2010**	**2011**	**2012**	**2015**	**2020**	**2025**	**2032**
Population [thousand]	528.9	537.8					
No of households [thousand]	53.6	54.7	55.8	59.2	65.3	71.9	81.3
Connection rate [%]	1.3	1.2	6.6	22.9	50.0	58.3	70.0
Gross electricity demand [GWh]	1.7	2.2	4.7	14.8	77.0	128.8	240.5
Net electricity demand [GWh]	1.2	1.5	3.3	10.6	57.2	98.2	187.4
Peak demand [MW]	0.4	0.5	1.0	3.1	16.0	26.7	45.8

Table 8.2.17-1: Load and load forecast for Khost

The expected load center will be the area around Khost, the capital of Khost province. The tentative location of a new substation at Khost is given in the table below.

Further load centers for Khost	Latitude N	Longitude E	
Khost	33°22'50"	70° 1'50"	*

* Substation coordinates estimated from map

Table 8.2.17-2: Further load centers for Khost

The tables below present the development of transformer capacity and transformer loading required to meet the growth in load in Khost during the planning horizon.

		Existing and further transformer capacity [MVA] Khost					
		2011	**2012**	**2015**	**2020**	**2025**	**2032**
Khost	2 x 16				32.0	32.0	32.0
Khost	1 x 16					16.0	16.0
Khost	1 x 16						16.0
Total		0	0	0	32	48	64

Table 8.2.17-3: Existing and further transformer capacity [MVA] for Khost

	Existing and further load at substation level [MW] for Khost						
		2011	2012	2015	2020	2025	2032
Khost					16.0	17.8	22.9
Khost						8.9	11.4
Khost							11.4
Total		0.0	0.0	0.0	16.0	26.7	45.8

Table 8.2.17-4: Existing and further load at substation level [MW] for Khost

Connection of the Khost region can be established from the expected substation at Gardez. Due to the expected load at Khost, the voltage level for connection is selected at 110 kV and a step-down transformer 220/110 kV at Gardez feeding directly into the 110 kV line is planned.

8.2.17.3 Overview

Network development in Khost province will be in stages as follows and CAPEX will be about $19.8m.

Stage A up to 2015:
The substation at Gardez will be the starting point for electrification of the Khost region and will be available in the period between 2015 and 2020. Therefore, no CAPEX is expected during Stage A.

Stage B up to 2020:
For Stage B, the proposed network development will cover the

(i) erection of a new substation 110/20 kV at Khost with two transformers 16 MVA each, expansion of Gardez substation with step-down transformer 220/110 kV with a capacity of 50 MVA and construction of a transmission line 110 kV Gardez to Khost with a length of about 100 km.

The estimated cost of network development in Stage B for the Khost region is about $18.1m and the single-line diagram for the transmission network in Khost in 2020 is given in **Annex 8.2.17-3**.

P_17_B						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Gardez	220KV	1			0.9	m$
transformer Gardez	220/110kV	1	50		1.0	m$
new substation Khost	110kV	3			3.5	m$
transformer Khost	110/20kV	2	16		0.7	m$
110kV line Gardez - Khost	1x3x1xACSR185			100	12.0	m$
Subtotal P_17_B					18.1	m$

Table 8.2.17-5: Additional CAPEX for power system in Khost up to 2020

Stage C up to 2025:
Load growth in Khost up to 2025 will require an

(i) additional transformer 110/20 kV at Khost with a capacity of 16 MVA.

Capital expenditure will be about $0.9m. The single-line diagram is given in **Annex 8.2.17-4**.

P_17_C						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Khost	110kV	1			0.5	m$
transformer Khost	110/20kV	1	16		0.3	m$
Subtotal P_17_C					0.9	m$

Table 8.2.17-6: Additional CAPEX for power system in Khost up to 2025

Stage C up to 2032:
Load growth in Khost up to 2032 will require an

(i) additional transformer 110/20 kV at Khost with a capacity of 16 MVA.

Capital expenditure will be about $0.9m. The single-line diagram is given in **Annex 8.2.17-5**.

P_17_D						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Khost	110kV	1			0.5	m$
transformer Khost	110/20kV	1	16		0.3	m$
Subtotal P_17_D					0.9	m$

Table 8.2.17-7: Additional CAPEX for power system in Khost up to 2032

8.2.18 Kunar

8.2.18.1 Existing system

Kunar province is located in the northeast of Afghanistan at the border with Pakistan. Currently, Kunar province is not connected to the national grid of Afghanistan. At present, the connection rate of households is reported as 5% from isolated generation systems.

8.2.18.2 Network expansion

For Kunar province, a peak load of 36 MW and a connection rate of 70% are predicted, as shown in the table below.

	Load and load forecast for Kunar						
Year	**2010**	**2011**	**2012**	**2015**	**2020**	**2025**	**2032**
Population [Thousand]	414.7	421.7					
No of Households [Thousand]	42.3	43.1	44.0	46.7	51.6	56.8	64.1
Connection rate [%]	5.3	5.2	10.2	25.1	50.0	58.3	70.0
Gross Electricity Demand [GWh]	1.7	2.1	3.6	12.4	60.7	101.7	189.8
Net Electricity Demand [GWh]	1.2	1.4	2.5	8.8	45.1	77.5	147.9
Peak Demand [MW]	0.4	0.4	0.7	2.6	12.6	21.1	36.1

Table 8.2.18-1: Load and load forecast for Kunar

The populated area is along the River Kunar, which crosses the province from northeast to southwest. The load center is expected around Asadabad, the capital of Kunar province.

Further load centers for Kunar	Latitude N	Longitude E	
Asadabad	34°52'10"	71°8'50"	*

* Substation coordinates estimated from map

Table 8.2.18-2: Further load centers for Kunar

Electrification of Kunar province will be possible from the new 110 kV substation at Jalalabad at the 110 kV level. The required transformer capacity at the load center and the expected loading are given in the following Table 8.2.18-3 and Table 8.2.18-4.

		Existing and further transformer capacity [MVA] Kunar					
		2011	**2012**	**2015**	**2020**	**2025**	**2032**
Asadabad	1 x 16				16.0	16.0	16.0
Asadabad	1 x 16					16.0	16.0
Asadabad	1 x 16						16.0
Total		0	0	0	16	32	48

Table 8.2.18-3: Existing and further transformer capacity [MVA] for Kunar

	Existing and further load at substation level [MW] for Kunar						
		2011	2012	2015	2020	2025	2032
Asadabad					12.6	10.5	12.0
Asadabad						10.5	12.0
Asadabad							12.0
Total		0.0	0.0	0.0	12.6	21.1	36.1

Table 8.2.18-4: Existing and further load at substation level [MW] for Kunar

There are large hydro resources along the Kunar River upstream of Asadabad and it is expected that projects will be realized by the end of the planning horizon. For evacuation of the power generated in Kunar A and B, a 500 kV transmission line will be constructed along the Kunar River as far as Jalalabad.

8.2.18.3 Overview

Connection of Kunar province to the national grid will be possible after erection of the 110 kV substation at Jalalabad. Network development for power supply (P_18) will require a CAPEX of about $16.1m. Reinforcement of the transmission system for connection of Kunar A, with a capacity of 789 MW, and Kunar B, with a capacity of 300 MW, will require CAPEX of about $86.8m (GN_05) and 33m$ (GN_10).

<u>Stage A up to 2015:</u>
For the first stage, the 110 kV substation at Jalalabad will not have been erected and, therefore, no development in Kunar province will be possible.

<u>Stage B up to 2020:</u>
Between 2015 and 2020, electrification will start with

(i) Erection of 110/20 kV substation at Asadabad with first transformer 16 ´MVA and 110 kV transmission line from Jalalabad to Asadabad with a length of about 85 km.

The estimated cost of this development stage is about $14.4m and the single-line diagram is given in **Annex 8.2.18-3**.

P_18_B Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Jalalabad	110kV	1			0.5	m$
new substation Asabadab	110kV	2			3.3	m$
transformer Asadabad	110/20kV	1	16		0.3	m$
110kV line Jalalabad - Asadabad	1x3x1xACSR185			85	10.2	m$
Subtotal P_18_B					14.4	m$

Table 8.2.18-5: Additional CAPEX for power system in Kunar up to 2020

Stage C up to 2025:
To meet load growth, an

(i) additional transformer 110/20 kV with a capacity of 16 MVA

will need to be installed by 2025. Capital expenditure will be about $0.9m and the single-line diagram is given in **Annex 8.2.18-4**.

P_18_C						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Asadabad	110kV	1			0.5	m$
transformer Asadabad	110/20kV	1	16		0.3	m$
Subtotal P_18_C					0.9	m$

Table 8.2.18-6: Additional CAPEX for power system in Kunar up to 2025

Stage D up to 2032:
In the period to 2032, an

(i) additional transformer 110/20 kV with a capacity of 16 MVA

will need to be installed to meet the growth in load.
Capital expenditure will be about $0.9m.

P_18_D						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Asadabad	110kV	1			0.5	m$
transformer Asadabad	110/20kV	1	16		0.3	m$
Subtotal P_18_D					0.9	m$

Table 8.2.18-7: Additional CAPEX for power system in Kunar up to 2032

Between 2025 and 2032, hydropower plants Kunar B and Kunar A are expected to be constructed.
For evacuation of the generated power from Kunar A and B, a 500 kV connection will be necessary. The 500 kV line will be routed to Jalalabad for connection to the line from Arghandi to Pakistan.

Network integration for Kunar A and Kunar B requires the following measures:

(i) erection of 500 kV substation at Kunar A HPP site with step-up transformer for Kunar A generation units
(ii) installation of step-up transformers to 500 kV for Kunar B generation units and routing of two lines 500 kV from Kunar B to Kunar A with a length of about 15 km
(iii) construction of 500 kV line from Kunar A to Jalalabad with a length of about 115 km.

CAPEX for integration of both power plants is about $120m. Due to the fact that most of the equipment is used partly by both power plants, the CAPEX will be split between the power plants according to their installed capacity and this will result in shares of $87m for Kunar A (GN_05) and $33m for Kunar B (GN_10).

G_05 + G_10_D	Additional CAPEX up to 2032					
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Jalalabad	500kV	1			3.3	m$
new substation Kunar A	500kV	9			34.4	m$
Step up transformer Kunar A	500/20kV	6	180		20.5	m$
Step up transformer Kunar B	500/20kV	2	240		9.1	m$
500kV line Kunar B - Kunar A	2x3x3xACSR400			15	8.8	m$
500kV line Kunar A - Jalalabad	1x3x3xACSR400			115	43.7	m$
Subtotal G_05 + G_10_D					119.8	m$

Table 8.2.18-8: CAPEX for network integration of Kunar A and B HPP up to 2032

The single-line diagram for transmission network development for Kunar province up to 2032 is given in **Annex 8.2.18-5**.

8.2.19 Kunduz

8.2.19.1 Existing system

Kunduz province is located north of Afghanistan at the border with Tajikistan. Currently, Kunduz is served via a 110 kV line from Tajikistan. There is one 110 kV substation north of the center of Kunduz and the connection rate of households in Kunduz was reported as 30% for 2011.

Existing load centers for Kunduz	Latitude N	Longitude E	
Kunduz	36°44'46.36"	68°51'54.37"	*

* Substation coordinates found in map

Table 8.2.19-1: Existing load centers for Kunduz

A 220 kV double-circuit line from Tajikistan to Pul-e-Chomri was recently erected and the line passes close to Kunduz. The single-line diagram of the existing network in Kunduz is given in **Annex 8.2.19-1**.

8.2.19.2 Network expansion

According to the demand forecast, peak load in Kunduz will increase from 24 MW in 2011 to 104 MW in 2032. The connection rate of households will reach 82%. The load forecast for Kunduz province is given in Table 8.2.19-2

	Load and load forecast for Kunduz						
Year	2010	2011	2012	2015	2020	2025	2032
Population [Thousand]	917.9	935.6					
No of Households [Thousand]	106.8	108.9	111.1	117.9	130.1	143.2	161.9
Connection rate [%]	23.2	29.7	36.4	56.6	73.0	78.0	82.5
Gross Electricity Demand [GWh]	81.2	115.3	135.2	197.9	290.2	382.2	544.8
Net Electricity Demand [GWh]	56.0	79.5	94.0	141.0	215.5	291.5	424.6
Peak Demand [MW]	16.9	23.9	28.1	41.1	60.2	79.3	103.7

Table 8.2.19-2: Load and load forecast for Kunduz

Kunduz city will be the main load center for Kunduz province. The populated areas extend along the River Khanabad from Khanabad city northwest to the Amudarya River and along the Amudarya River to the north of Kunduz. The locations of substations to serve future loads are taken from the map and the preliminary locations are given in Table 8.2.19-3 below.

Further load centers for Kunduz	Latitude N	Longitude E	
Imam Sahib	37°8'10"	68°55'10"	**
Dasht-e Archi	37° 6'10"	69° 8'30"	**
Qala-I-Zal	36°56'50"	68°35'20"	**
Khanabad	36°42'25"	69° 8'50"	**
Kunduz 2	36°49'26.38"	68°52'0.60"	*

* Substation coordinates given by DABS (DBS_031)

** Substation coordinates estimated from map

Table 8.2.19-3: Further load centers for Kunduz

The load centers at Imam Sahib and Dasht-e Archi along the Amudarya River in the north will be supplied from a t-off along the 110 kV line. For reinforcement of the power supply in Kunduz region, a new substation with loop-in of the 220 kV line will be erected and the 110 kV system will be expanded.

To serve the additional loads in the existing and new load centers, the following transformer capacity must be installed:

	Existing and further transformer capacity [MVA] Kunduz							
			2011	2012	2015	2020	2025	2032
Kunduz	2 x	16	32.0	32.0	32.0	32.0	32.0	32.0
Kunduz	1 x	16				16.0	16.0	16.0
Kunduz 2	*							
Imam Sahib	1 x	16		16.0	16.0	16.0	16.0	16.0
Dasht-e Archi	1 x	16			16.0	16.0	16.0	16.0
Qala-I-Zal	1 x	16				16.0	16.0	16.0
Khanabad	1 x	16					16.0	16.0
Total			32	48	64	96	112	112

* Only interbus transformer 220/110 kV

Table 8.2.19-4: Existing and further transformer capacity [MVA] for Kunduz

The expected loading of the transformers is given in Table 8.2.19-5.

	Existing and further load at substation level [MW] for Kunduz						
		2011	2012	2015	2020	2025	2032
Kunduz		23.9	18.7	20.5	20.1	22.7	29.6
Kunduz					10.0	11.3	14.8
Kunduz 2	*						
Imam Sahib			9.4	10.3	10.0	11.3	14.8
Dasht-e Archi				10.3	10.0	11.3	14.8
Qala-I-Zal					10.0	11.3	14.8
Khanabad						11.3	14.8
Total		23.9	28.1	41.1	60.2	79.3	103.7

* Only interbus transformer 220/110 kV

Table 8.2.19-5: Existing and further load at substation level [MW] for Kunduz

8.2.19.3 Overview

Total CAPEX for the transmission system in Kunduz province (P_19) will be $40.9m. Details of the different development stages are as follows.

Stage A up to 2015:
The ongoing projects in Kunduz province for

(i) erection of new substation 110/20 kV at Imam Sahib with transformer 16 MVA and t-in line with a length of about 18 km from the existing 110 kV line Geran to Kunduz
(ii) erection of new substation 110/20 kV at Dasht-e Archi with transformer 16 MVA and line with a length of about 22 km from Imam Sahib to Dasht-e Archi
(iii) erection of new 220/110 kV substation at Kunduz 2 with interbus transformer 40 MVA and 25 MVA, loop-in of one circuit of the existing 220 kV line from Sangtuda to Pul-e-Chomri and 110 kV line from Kunduz 2 to Kunduz with a length of 8 km.

The estimated cost of expansion Stage A is about $25.6m. Major parts of this amount have already been financed by international donors. The resulting network configuration for Kunduz province up to 2015 is given in **Annex 8.2.19-2**.

P_19_A Measure	Type	No	[MVA]	[km]	Cost	
new substation Imam Sahib	110kV	3			3.5	m$
transformer Imam Sahib	1100/20kV	1	16		0.3	m$
new substation Dasht-e Archi	110kV	2			3.3	m$
transformer Dasht-e Archi	110/20kV	1	16		0.3	m$
expansion substation Kunduz	110kV	1			0.5	m$
new substation Kunduz 2	220kV	4			7.0	m$
new substation Kunduz 2	110kV	3			3.5	m$
transformer Kunduz 2	220/110kV	1	40		0.8	m$
transformer Kunduz 2	220/110kV	1	25		0.5	m$
110 kV line Kunduz 2 - Kunduz	1x3x1xACSR185			8	1.0	m$
110 kV line t-off - Imam Sahib	1x3x1xACSR185			18	2.2	m$
110 kV line Im. Sahib - Dasht-e Archi	1x3x1xACSR185			22	2.6	m$
Subtotal P_19_A					25.6	m$

Table 8.2.19-6: CAPEX for power system in Kunduz up to 2015

Stage B up to 2020:
The next stage for further transmission network development in Kunduz province will be

(i) erection of new substation 110/20 kV at Qala-I-Zal with transformer 16 MVA and 110 kV transmission line from Kunduz 2 to Qala-I-Zalwith with a length of about 29 km
(ii) installation of an additional transformer 110/20 kV with a capacity of 16 MVA at Kunduz.

The required capital expenditure for this expansion stage is estimated at $8.5m. The single-line diagram of the transmission system in Kunduz after commissioning of Stage B projects is given in **Annex 8.2.19-3**.

P_19_B Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Kunduz 2	110kV	1			0.5	m$
new substation Qala-I-Zal	110kV	2			3.3	m$
transformer Qala-I-Zal	110/20kV	1	16		0.3	m$
expansion substation Kunduz	110kV	1			0.5	m$
transformer Kunduz	110/20kV	1	16		0.3	m$
110kV line Kunduz 2 - Qala-L-Zal	1x3x1xACSR185			29	3.5	m$
Subtotal P_19_B					8.5	m$

Table 8.2.19-7: Additional CAPEX for power system in Kunduz up to 2020

Stage C up to 2025:
Creation of a further infeed to the Kunduz area will require a

(i) new substation 220/20 kV at Khanabad with transformer 16 MVA and loop-in of the 220 kV line from Kunduz 2 to Taluqan; the distance between Kunduz 2 and the new substation at Khanabad is about 30 km.

The single-line diagram after installation of the Stage C equipment is given in **Annex 8.2.19-4** and the estimated CAPEX for Stage C is about $6.8m.

P_19_C Measure	Type	No	[MVA]	[km]	Cost	
new substation Khanabad	220kV	3			6.5	m$
transformer Khanabad	220/20kV	1	16		0.3	m$
Subtotal P_19_C					6.8	m$

Table 8.2.19-8: Additional CAPEX for power system in Kunduz up to 2025

Stage D up to 2032:
Stage D will require no additional CAPEX on the transmission network to meet the growth in demand in Kunduz province.

In case that Kukcha hydropower plant will go into operation by 2032 network integration of the power plant will be achieved by routing an additional 220 kV line to Kunduz 2 and loop-in of the second circuit of the line from Sangtuda to Pul-e-Chomri to Kunduz 2 substation. The single-line diagram showing the transmission network development for Kunduz province for 2032 is given in **Annex 8.2.19-5**. The CAPEX for network integration of Kukcha HPP is considered in section 8.2.1.

8.2.20 Laghman

8.2.20.1 Existing system

Laghman province is located to the east of Kabul has been connected recently to the national grid by commissioning of the new 110 kV line from Jalalabad to Mehtarlam. Until then Laghman was not connection to the national grid. The connection rate of households reported for 2011 was about 3% and the power supply is by small isolated units.

8.2.20.2 Network expansion

The expected peak load for 2032 will be about 35 MW with a connection rate of 70% according to the demand forecast, as shown in the following table.

	Load and load forecast for Laghman						
Year	2010	2011	2012	2015	2020	2025	2032
Population [Thousand]	410.3	417.2					
No of Households [Thousand]	41.3	42.2	43.0	45.6	50.4	55.5	62.7
Connection rate [%]	2.4	3.2	8.4	24.0	50.0	58.3	70.0
Gross Electricity Demand [GWh]	1.1	1.7	4.9	18.4	59.4	99.3	185.5
Net Electricity Demand [GWh]	0.8	1.1	3.4	13.1	44.1	75.8	144.6
Peak Demand [MW]	0.2	0.3	1.0	3.8	12.3	20.6	35.3

Table 8.2.20-1: Load and load forecast for Laghman

The expected load center in Laghman province will be the region around Mehtarlam along the valleys north of Jalalabad. Therefore, the new substation to supply the province will be located at Metharlam. A possible tentative location was taken from the map.

Further load centers for Laghman	Latitude N	Longitude E	
Mehtarlam	34°40'30"	70°12'40"	*

* Substation coordinates estimated from map

Table 8.2.20-2: Further load centers for Laghman

The transformer capacity to be installed at Mehtarlam and the expected loading are given in Table 8.2.20-3 and Table 8.2.20-4 below.

		Existing and further transformer capacity [MVA] Laghman					
		2011	2012	2015	2020	2025	2032
Mehtarlam	1 x 16		16.0	16.0	16.0	16.0	16.0
Mehtarlam	1 x 16					16.0	16.0
Mehtarlam	1 x 16						16.0
Total		0	16	16	16	32	48

Table 8.2.20-3: Existing and further transformer capacity [MVA] for Laghman

	Existing and further load at substation level [MW] for Laghman						
		2011	2012	2015	2020	2025	2032
Mehtarlam			1.0	3.8	12.3	10.3	11.8
Mehtarlam						10.3	11.8
Mehtarlam							11.8
Total		0.0	1.0	3.8	12.3	20.6	35.3

Table 8.2.20-4: Existing and further load at substation level [MW] for Laghman

8.2.20.3 Overview

Transmission network development in Laghman province (P_20) for serving the loads will be staged over the planning horizon and will require a CAPEX of about $1.8m. Network integration of the new hydropower plant at Sarobi (GN_04) will require $13m.

The first stage of development comprising

(i) Erection of a new 110/20 kV substation at Mehtarlam with transformer 16 MVA and 110 kV transmission line from Jalalabad to Mehtarlam with a length of about 35 km.

has been completed recently.

<u>Stage B up to 2020:</u>
In the period 2015 to 2020, no additional CAPEX on the transmission network will be required to meet the expected load growth in Laghman province.

<u>Stage C up to 2025:</u>
An increase in load will require an

(i) Additional transformer at Mehtarlam with a capacity of 16 MVA.

CAPEX for this stage will be about $0.9m and the single-line diagram for this development stage is given in **Annex 8.2.20-3**.

P_20_C Measure	Type	No	[MVA]	[km]	Cost	
expansion subst. Mehtarlam	110kV	1			0.5	m$
transformer Mehtarlam	110/20kV	1	16		0.3	m$
Subtotal P_20_C					0.9	m$

Table 8.2.20-5: Additional CAPEX for power system in Laghman up to 2025

<u>Stage D up to 2032:</u>
Meeting the increase in load up to 2032 will require an

(i) additional transformer at Mehtarlam with a capacity of 16 MVA.

CAPEX for this stage will be about $0.9m.

P_20_D Measure	Type	No	[MVA]	[km]	Cost	
expansion subst. Mehtarlam	110kV	1			0.5	m$
transformer Mehtarlam	110/20kV	1	16		0.3	m$
Subtotal P_20_D					0.9	m$

Table 8.2.20-6: Additional CAPEX for power system in Laghman up to 2032

In addition to the network development required for power supply in the province, network integration of an optional hydropower plant at Sarobi (GN_04), located in Laghman province, is taken into consideration with

(i) Erection of a new substation 220 kV at Sarobi 2 with step-up transformers for the generation units and loop-in of the new line 220 kV from Naghlu to Jalalabad.

G_04_D Measure	Additional CAPEX up to 2032 Type	No	[MVA]	[km]	Cost	
new substation Sarobi 2	220kV	8			8.6	m$
transformer Sarobi 2	220/20kV	6	37.5		4.6	m$
Subtotal G_04_D					13.2	m$

Table 8.2.20-7: CAPEX for network integration of Sarobi HPP up to 2032

The single-line diagram for network expansion in Laghman province is given in **Annex 8.2.20-5**.

8.2.21 Logar

8.2.21.1 Existing system

Logar province is located to the south of Kabul and currently has no power supply from the national grid. A low connection rate of about 2% was reported for Logar province in 2011.

8.2.21.2 Network expansion

Demand in Logar province will increase and peak load will reach 31 MW with a connection rate of 70%.

	Load and load forecast for Logar						
Year	2010	2011	2012	2015	2020	2025	2032
Population [Thousand]	360.9	367.0					
No of Households [Thousand]	36.7	37.4	38.2	40.5	44.7	49.2	55.6
Connection rate [%]	1.3	1.9	7.2	23.3	50.0	58.3	70.0
Gross Electricity Demand [GWh]	0.4	0.6	2.3	9.9	52.7	88.2	164.6
Net Electricity Demand [GWh]	0.3	0.4	1.6	7.1	39.1	67.2	128.3
Peak Demand [MW]	0.1	0.1	0.5	2.1	10.9	18.3	31.3

Table 8.2.21-1: Load and load forecast for Logar

The load center will be the area along the Kabul - Gardez road as far as Pul-e-Alam and from Pul-e-Alam in the direction of the valleys to the west and southwest.

Therefore, the new bulk supply point for Logar province will be located at Pul-e-Alam.

Further load centers for Logar	Latitude N	Longitude E	
Pul-e-Alam	33°59'	69° 2'30"	*

* Substation coordinates estimated from map

Table 8.2.21-2: Further load centers for Logar

The transformer capacity required for meeting demand in Logar and the expected loading are given in the tables below.

		Existing and further transformer capacity [MVA] Logar					
		2011	2012	2015	2020	2025	2032
Pul-e-Alam	2 x 16				32.0	32.0	32.0
Pul-e-Alam	1 x 16						16.0
Total		0	0	0	32	32	48

Table 8.2.21-3: Existing and further transformer capacity [MVA] for Logar

	Existing and further load at substation level [MW] for Logar						
		2011	2012	2015	2020	2025	2032
Pul-e-Alam					10.9	18.3	20.9
Pul-e-Alam							10.4
Total		0.0	0.0	0.0	10.9	18.3	31.3

Table 8.2.21-4: Existing and further load at substation level [MW] for Logar

Power supply to Logar province can be achieved from the new substation at Sayad Abad along the NEPS to SEPS interconnector at the 220 kV level. The expected load from Logar itself will not justify a voltage level of 220 kV, although other provinces, such as Paktia and Kost, will be served from the new substation at Pul-e-Alam.

8.2.21.3 Overview

Expansion in Logar province in the different stages will require a total CAPEX of about $19.1m.

<u>Stage A up to 2015:</u>
Power supply for Logar will use the new substation at Arghandi, which will be available after 2015. Up to 2015, therefore, no CAPEX on transmission network development is expected.

<u>Stage B up to 2020:</u>
In the period 2015 to 2020

(i) erection of new substation 220/20 kV at Pul-e-Alam with two transformers each with a capacity of 16 MVA and construction of 220 kV line from Arghandi to Pul-e-Alam with a length of about 50 km

is expected. The required CAPEX for this expansion is estimated at about $17.6m and **Annex 8.2.21-3** shows the network development in Logar up to 2020.

P_21_B Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Arghanid	220kV	1			0.9	m$
new substation Pul-e-Alam	220kV	3			6.5	m$
transformer Pul-e-Alam	220/20kV	2	16		0.7	m$
220kV line Arghandi - Pul-e-A.	1x3x1xACSR300			32	9.5	m$
Subtotal P_21_B					17.6	m$

Table 8.2.21-5:Additional CAPEX for power system in Logar up to 2020

<u>Stage C up to 2025:</u>
In Stage C, no CAPEX is required for the transmission network in Logar province.

Stage D up to 2032:
To meet load growth up to 2032, installation of an

(i) additional transformer at Pul-e-Alam 220/20 kV with a capacity of 16 MVA

will be required with an estimated CAPEX of about $1.6m.

The single-line diagram for the transmission system in Logar for development up to 2032 is given in **Annex 8.2.21-5**.

P_21_D Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Pul-e-A.	220kV	1			0.9	m$
transformer Pul-e-Alam	220/20kV	2	16		0.7	m$
Subtotal P_21_D					1.6	m$

Table 8.2.21-6: Additional CAPEX for power system in Logar up to 2032

8.2.22 Nangarhar

8.2.22.1 Existing system

The province of Nangarhar to the east of Kabul province has been connected recently to the national grid by commissioning of the new 110 kV line from Naghlu to Jalalabad. Until then the system in Nangarhar were operated as an island system, which was supplied mainly from Darunta hydropower station. The connection rate of households in Nangarhar was reported as about 7% in 2011.

Existing Load C. Nangarhar	Latitude N	Longitude E	
Jalalabad	34°26'2.96"	70°26'52.17"	**
Existing Power Plants	**Latitude N**	**Longitude E**	
Darunta	34°28'58"	70°21'46.8"	*

* Substation coordinates found in map

** Substation coordinates estimated from map

Table 8.2.22-1: Existing load centers for Nangarhar

The single-line diagram of the existing system in Nangarhar province is given in **Annex 8.2.22-1**.

8.2.22.2 Network expansion

According to the demand forecast for Nangarhar (Table 8.2.22-2), peak load in 2032 is expected to be about 100 MW and the connection rate will reach 70%.

	Load and load forecast for Nangarhar						
Year	2010	2011	2012	2015	2020	2025	2032
Population [thousand]	1383.9	1409.6					
No of households [thousand]	151.6	154.7	157.8	167.4	184.8	203.5	229.9
Connection rate [%]	6.9	7.2	12.0	26.2	50.0	58.3	70.0
Gross electricity demand [GWh]	45.7	40.6	55.8	114.2	259.7	351.5	518.3
Net electricity demand [GWh]	31.5	28.0	38.8	81.4	192.9	268.1	404.0
Peak demand [MW]	9.5	8.4	11.6	23.7	53.9	72.9	98.6

Table 8.2.22-2: Load and load forecast for Nangarhar

The populated area extends around Jalalabad, the capital of the province, along the valley of the Kunar River and its tributaries.

There is an ongoing project to connect Jalalabad to Naghlu HPP at the 110 kV level.

The 110 kV substation at Jalalabad will be the connecting point for the province of Laghman.

The expected load increase in Nangarhar province may require additional 110 kV substations along the populated valleys. Development of the installed transformer capacity in Nangarhar province and the expected loading of the transformers is given in the tables below.

	Existing and further transformer capacity [MVA] Nangarhar						
		2011	2012	2015	2020	2025	2032
Jalalabad	2 x 16			32.0	32.0	32.0	32.0
	2 x 16				32.0	32.0	32.0
Jalalabad 2	2 x 16					32.0	32.0
Jalalabad 3	2 x 16						32.0
Total		0	0	32	64	96	128

Table 8.2.22-3: Existing and further transformer capacity [MVA] for Nangarhar

	Existing and further load at substation level [MW] for Nangarhar						
		2011	2012	2015	2020	2025	2032
Jalalabad		8.4	11.6	23.7	27.0	24.3	24.7
					27.0	24.3	24.7
Jalalabad 2						24.3	24.7
Jalalabad 3							24.7
Total		8.4	11.6	23.7	53.9	72.9	98.6

Table 8.2.22-4: Existing and further load at substation level [MW] for Nangarhar

8.2.22.3 Overview

Network development in the different stages for Nangarhar province (P_22) will require CAPEX of about $45.2m.

The first stage of development comprising

(i) erection of new substation 110 kV at Jalalabad feeding the 35 kV system with two transformers 16 MVA each and construction of 110 kV line from Naghlu to Jalalabad with a length of about 75 km

has been completed recently.

<u>Stage B up to 2020:</u>
Load growth in Nangarhar province will require the

(i) installation of two additional transformers at Jalalabad each with a capacity of 16 MVA, which will require a CAPEX of about $1.7m.

P_22_B Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Jalalabad	110kV	2			1.1	m$
transformer Jalalabad	110/35kV	2	16		0.7	m$
Subtotal P_22_B					1.7	m$

Table 8.2.22-5: Additional CAPEX for power system in Nangarhar up to 2020

Annex 8.2.22-3 shows the single-line diagram for this development stage.

<u>Stage C up to 2025:</u>
Load growth up to 2025 will require infeed to the region at a higher voltage level as well as additional transformer capacity. Therefore, the following measures are planned in Stage C:

(i) erection of 220 kV substation at Jalalabad with three interbus transformers 50 MVA each and 220 kV transmission line from Naghlu to Jalalabad with a length of about 75 km. This line will pass by the proposed site of Surobi 2 HPP
(ii) erection of an additional 110 kV substation Jalalabad 2 in Jalalabad region with two 110/20 kV transformers each with a capacity of 16 MVA and 110 kV connection between Jalalabad and Jalalabad 2 with an assumed length of about 30 km.

Expansion Stage C will require CAPEX of about $35.1m and the single-line diagram is given in **Annex 8.2.22-4**.

P_22_C Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Naghlu	220kV	1			0.9	m$
new substation Jalalabad	220kV	4			7.0	m$
expansion substation Jalalabad	110kV	4			2.2	m$
interbus transformer Jalalabad	220/110kV	3	50		3.1	m$
new substation Jalalabad 2	110kV	3			3.5	m$
transformer Jalalabad 2	110/20kV	2	16		0.7	m$
220kV line Naghlu - Jalalabad	1x3x1xACSR300			75	14.3	m$
110kV line Jalalabad - Jalalabad2	1x3x1xACSR185			30	3.6	m$
Subtotal P_22_C					35.1	m$

Table 8.2.22-6: Additional CAPEX for power system in Nangarhar up to 2025

<u>Stage D up to 2032:</u>
The increase in load in the Jalalabad region will require an

(i) Additional substation 110 kV Jalalabad 3 in the Jalalabad region with two 110/20 kV transformers each with a capacity of 16 MVA and 110 kV connection between Jalalabad and Jalalabad 3 with an assumed length of about 30 km.

Expansion Stage C will require CAPEX of about $8.3m.

P_22_D						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Jalalabad	110kV	1			0.5	m$
new substation Jalalabad 3	110kV	3			3.5	m$
transformer Jalalabad 3	110/20kV	2	16		0.7	m$
110kV line Jalalabad - Jalalabad3	1x3x1xACSR185			30	3.6	m$
Subtotal P_22_D					8.3	m$

Table 8.2.22-7: Additional CAPEX for power system in Nangarhar up to 2032

The single-line diagram for network development up to 2032 is given in **Annex 8.2.22-4**. This also includes the 500 kV substation at Jalalabad with interbus transformer and the 500 kV transmission line from Arghandi to Jalalabad and on to the Pakistan border, which is treated as major transmission project T_04 in section 6.3.

Network integration of an optional 45 MW hydropower plant at Kama will be possible at the 110 kV level by routing the line to the 110 kV substation at Jalalabad. Kama HPP was not chosen during the optimization process and, therefore, its network integration was not considered.

8.2.23 Nimruz

8.2.23.1 Existing system

Currently, Nimruz province is supplied by import line from Iran at the 20 kV level. A high connection rate of 97.6% is reported for Nimruz.

Existing load centers for Nimruz	Latitude N	Longitude E	
Zaranj (Iran supply)	20°57'	61°51'	*

* Substation coordinates estimated from map

Table 8.2.23-1: Existing load centers for Nimruz

The load center is located near to the border with Iran. The single-line diagram of the existing system is given in Annex 8.2.23-1.

8.2.23.2 Network expansion

According to the load forecast, the peak load in 2032 is expected to be about 52 MW.

	Load and load forecast for Nimruz						
Year	2010	2011	2012	2015	2020	2025	2032
Population [thousand]	151.1	153.9					
No of households [thousand]	16.7	17.0	17.4	18.4	20.3	22.4	25.3
Connection rate [%]	73.8	97.6	97.8	98.5	99.0	99.0	99.0
Gross electricity demand [GWh]	71.1	104.3	110.4	126.4	157.4	197.9	272.0
Net electricity demand [GWh]	49.1	71.9	76.7	90.0	116.9	151.0	212.0
Peak demand [MW]	14.8	21.6	22.9	26.2	32.7	41.1	51.7

Table 8.2.23-2: Load and load forecast for Nimruz

Nimruz province is located in the southwest of Afghanistan at the border with Iran. The high connection rate in Nimruz indicates that nearly the entire demand is supplied. Therefore, no immediate need is indicated for reinforcement of the system apart from continuous expansion of the distribution system. The distance between the load center at Zaranj, the capital of the province, and Lashkargah, which is the nearest substation in the Afghan national grid, is about 250 km. This leads us to recommend continuing of power supply to Nimruz by import from Iran.

If Nimruz is to be connected to the national grid, the following transformer capacities must be installed at the new 110/20 kV substation at Zaranj.

	Existing and further transformer capacity [MVA] Nimruz						
		2011	2012	2015	2020	2025	2032
Zaranj (Iran supply) Zaranj (AFG supply)	3 x 20					60.0	60.0
Total		0	0	0	0	60	60

Table 8.2.23-3: Existing and further transformer capacity [MVA] for Nimruz

The expected loading of the transformers is as follows:

	Existing and further load at substation level [MW] for Nimruz						
		2011	2012	2015	2020	2025	2032
Zaranj (Iran supply)		21.6	22.9	26.2	32.7		
Zaranj (AFG supply)						41.1	51.7
Total		21.6	22.9	26.2	32.7	41.1	51.7

Table 8.2.23-4: Existing and further load at substation level [MW] for Nimruz

8.2.23.3 Overview

In the first stages, demand in Nimruz will be supplied from Iran.
Connection of Nimruz to the Afghan national grid will result in a CAPEX of about $34.9m. The voltage drop along the line will be dramatic and the voltage level of 110 kV for this distance and loading is not adequate.

Stage C up to 2025:
If Nimruz is connected to the Afghan national grid, the following measures will be required:

(i) erection of new 110/20 kV substation at Zaranj with three transformers each with a capacity of 20 MVA and construction of a 110 kV transmission line from Lashkargah to Zaranj with a length of about 250 km.

The expected CAPEX required for these measures is about $34.9m and the single-line diagram for development Stage C is given in **Annex 8.2.23-4**.

P_23_C Measure	Type	No	[MVA]	[km]	Cost	
expansion subst. Lashkargah	110kV	1			0.5	m$
new substation Zaranj	110kV	4			3.7	m$
transformer Zaranj	110/20kV	3	20		1.2	m$
110kV line Lashkargah - Zaranj	1x3x1xACSR185			250	30.0	m$
Subtotal P_23_C					34.9	m$

Table 8.2.23-5: Additional CAPEX for power system in Nimruz up to 2025

Stage D up to 2032:
For the period 2025 to 2032, no additional measures for reinforcement of the transmission network are required.

8.2.24 Nuristan

8.2.24.1 Existing system

Nuristan is located in the northeast of Afghanistan at the border with Pakistan and is embedded in the south of the Hindu Kush valleys. Currently, there is no connection to the national grid of Afghanistan.

8.2.24.2 Network expansion

According to the demand forecast, the peak load in 2032 is expected to be about 9 MW with a connection rate of households of 65%.

	Load and load forecast for Nuristan						
Year	**2010**	**2011**	**2012**	**2015**	**2020**	**2025**	**2032**
Population [Thousand]	136.3	138.6					
No of Households [Thousand]	13.6	13.9	14.2	15.0	16.6	18.3	20.7
Connection rate [%]	0.0	0.0	0.0	10.0	35.0	53.3	65.0
Gross Electricity Demand [GWh]	0.0	0.0	0.0	0.7	9.6	25.1	48.6
Net Electricity Demand [GWh]	0.0	0.0	0.0	0.5	7.1	19.2	37.9
Peak Demand [MW]	0.0	0.0	0.0	0.2	2.0	5.2	9.2

Table 8.2.24-1: Load and load forecast for Nuristan

Nuristan province in the Hindu Kush valley is sparsely populated and no concentrated load centers can be identified. Therefore, a local power supply system using renewable resources and/or combined supply options with generation by diesel generator sets is recommended for Nuristan province. Load centers apart from the capital of the province could not be identified.

Further load centers for Nuristan	Latitude N	Longitude E	
Parun	35°25'40"	70°55'	*
Load Region 2	TBD	TBD	
Load Region 3	TBD	TBD	
Load Region 4	TBD	TBD	
Load Region 5	TBD	TBD	

* Substation coordinates estimated from map

Table 8.2.24-2: Further load centers for Nuristan

For this load center, the expected peak load to be covered by isolated operating systems is given in the following table.

	Existing and further load at substation level [MW] for Nuristan						
		2011	2012	2015	2020	2025	2032
Parun					1.0	1.7	1.5
Parun							1.5
Load Region 2					1.0	1.7	1.5
Load Region 3						1.7	1.5
Load Region 4							1.5
Load Region 5							1.5
Total		0.0	0.0	0.0	2.0	5.2	9.2

Table 8.2.24-3: Existing and further load centers [MW] for Nuristan

8.2.24.3 Overview

For Nuristan province, it is recommended to start with single house power supply systems. Larger units can be installed at later stages in towns. No transmission network will be developed in Nuristan province. It is recommended to use local units for households, towns and cities. Details of requirements for the different systems could not be given at the stage of the master plan, but should be developed as part of a detailed investigation of the province.

<u>Stage A up to 2015:</u>
In the first Stage A, the following is recommended:

(i) installation of single house units for a total of about 0.2 MW.

<u>Stage B up to 2020:</u>
Up to year 2020, installation of

(i) distribution networks for Parun and a second load center with local isolated generation

is expected.

<u>Stage C up to 2025:</u>
For 2025, installation of

(i) distribution system with local isolated generation for a third load center

is expected.

<u>Stage D up to 2032:</u>
In Stage D of development, the

(i) installation of a second system in Parun
(ii) installation of distribution networks for two additional load centers with local isolated generation

is expected.

8.2.25 Paktia

8.2.25.1 Existing system

Paktia province is located to the south of Logar province. Currently, Paktia province is not connected to the national power grid and there is no power supply available.

8.2.25.2 Network expansion

Power demand will increase by 2032 to an expected peak load of about 27 MW and the connection rate of households will reach 65%.

	Load and load forecast for Paktia						
Year	2010	2011	2012	2015	2020	2025	2032
Population [Thousand]	400.5	516.3					
No of Households [Thousand]	40.2	40.9	41.7	44.3	48.9	53.8	60.8
Connection rate [%]	4.0	0.0	0.0	10.0	35.0	53.3	65.0
Gross Electricity Demand [GWh]	0.0	0.0	0.0	2.2	28.2	74.0	143.0
Net Electricity Demand [GWh]	0.0	0.0	0.0	1.5	21.0	56.4	111.4
Peak Demand [MW]	0.0	0.0	0.0	0.5	5.9	15.4	27.2

Table 8.2.25-1: Load and load forecast for Paktia

The expected load center will be Gardez, the capital of Paktia province, and the tentative location of the new substation is given in the following Table 8.2.25-2:

Further load centers for Paktia	Latitude N	Longitude E	
Gardez	33°37'	69°12'30"	*

* Substation coordinates estimated from map

Table 8.2.25-2: Further load centers for Paktia

The required transformer capacity to be installed in Paktia province is given in Table 8.2.25-3 and Table 8.2.25-4 shows the expected loading of the transformers over the time horizon.

	Existing and further transformer capacity [MVA] Paktia						
		2011	2012	2015	2020	2025	2032
Gardez	2 x 16				32.0	32.0	32.0
	1 x 16						16.0
Total		0	0	0	32	32	48

Table 8.2.25-3: Existing and further transformer capacity [MVA] for Paktia

	Existing and further load at substation level [MW] for Paktia						
		2011	2012	2015	2020	2025	2032
Gardez					5.9	15.4	18.1 9.1
Total		0.0	0.0	0.0	5.9	15.4	27.2

Table 8.2.25-4: Existing and further load at substation level [MW] for Paktia

Connection to the network will be possible from the new substation at Pul-e-Alam.

The load expected for Paktia does not justify a voltage level of 220 kV. Due to the fact that Gardez is on the route to Khost as the load center of Khost province, the loading of the line will increase by supplying Khost and a voltage level of 220 kV is justified.

8.2.25.3 Overview

The proposal for staged development of the transmission system in Paktia is given in the following and the required CAPEX will be a total of about $18.2m.

<u>Stage A up to 2015:</u>
Development of the system will start from the substation at Pul-e-Alam and, therefore, up to 2015, no CAPEX is expected for the transmission system of Paktia.

<u>Stage B up to 2020:</u>
For Stage B, the following measures for network development in Paktia are proposed:

(i) Erection of 220 kV substation at Gardez with two transformers with a capacity of 16 MVA and construction of 220 kV line Pul-e-Alam to Gardez with a length about 47 km.

The required CAPEX for Stage B is estimated at about $17m and the single-line diagram for the expansion stage is given in **Annex 8.2.25-3**.

P_26_B						
Measure	Type	No	[MVA]	[km]	Cost	
expansion subst. Pul-e-Alam	220kV	1			0.9	m$
new substation Gardez	220kV	3			6.5	m$
transformer Gardez	220/20kV	2	16		0.7	m$
220kV line Pul-e-Alem - Gardez	1x3x1xACSR300			47	8.9	m$
Subtotal P_26_B					17.0	m$

Table 8.2.25-5:Additional CAPEX for power system in Paktia up to 2020

<u>Stage C up to 2025:</u>
In the period 2020 to 2025, no CAPEX is required for the transmission network of Paktia to cover load growth.

Stage D up to 2032:
To meet load growth up to 2032, it is necessary to install an

(i) Additional transformer 220/20 kV at Gardez with a transformer capacity of 16 MVA.

CAPEX will be about $1.2m and the single-line diagram is given in **Annex 8.2.25-5**.

P_26_D						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Gardez	220kV	1			0.9	m$
transformer Gardez	220/20kV	1	16		0.3	m$
Subtotal P_26_D					1.2	m$

Table 8.2.25-6:Additional CAPEX for power system in Paktia up to 2032

8.2.26 Paktika

8.2.26.1 Existing system

Paktika province is located in the southeast of Afghanistan at the border with Pakistan There is no power supply from the national grid in Paktika province and, in 2011, about 5% of households were connected to the power supply.

8.2.26.2 Network expansion

According to the demand forecast, peak demand in 2032 will increase to 34 MW with a connection rate of households of 70%.

	Load and load forecast for Paktika						
Year	2010	2011	2012	2015	2020	2025	2032
Population [Thousand]	507.8	407.1					
No of Households [Thousand]	52.3	41.0	41.8	44.4	49.0	54.0	61.0
Connection rate [%]	0.0	4.5	9.6	24.7	50.0	58.3	70.0
Gross Electricity Demand [GWh]	0.6	0.8	2.4	11.6	57.8	96.7	180.5
Net Electricity Demand [GWh]	0.4	0.6	1.6	8.2	42.9	73.7	140.7
Peak Demand [MW]	0.1	0.2	0.5	2.4	12.0	20.1	34.3

Table 8.2.26-1: Load and load forecast for Paktika

The populated area in Paktika province is mainly along the valley, extending from Gardez in a southwest direction parallel to the A1 ring road. With regard to power supply, it is expected that two substations will be erected in the province: one substation in the north of the province at Sharan and the other in the south and called Paktika. The tentative locations of the new substations are listed below.

Further load centers for Paktika	Latitude N	Longitude E	
Sharan	33° 8'30"	68°49'	*
Paktika	32°35'	68°15'	*

* Substation coordinates estimated from map

Table 8.2.26-2: Further load centers for Paktika

It is assumed that the load will be shared equally between the new substations and the required transformer capacity and expected loading over the planning horizon are given in the tables below.

	Existing and further transformer capacity [MVA] Paktika						
		2011	2012	2015	2020	2025	2032
Sharan	1 x 10				10.0	10.0	10.0
Sharan	1 x 10						10.0
Paktika	1 x 10				10.0	10.0	10.0
Paktika	1 x 10						10.0
Total		0	0	0	20	20	40

Table 8.2.26-3: Existing and further transformer capacity [MVA] for Paktika

	Existing and further load at substation level [MW] for Paktika						
		2011	2012	2015	2020	2025	2032
Sharan					6.0	10.0	8.6
Sharan							8.6
Paktika					6.0	10.0	8.6
Paktika							8.6
Total		0.0	0.0	0.0	12.0	20.1	34.3

Table 8.2.26-4: Existing and further load at substation level [MW] for Paktika

Power supply to the new substations will be possible at the 110 kV level from Ghazni and from Gelan substation.

8.2.26.3 Overview

Network development for Paktika province will start in the period between 2015 and 2020 when the substations in Ghazni province are available. Total CAPEX is estimated at $19.7m for development up to 2032.

<u>Stage A up to 2015:</u>
In the first period, no CAPEX will be possible.

<u>Stage B up to 2020:</u>
For network development in Stage B, the following measures are proposed:

(i) erection of 110/20 kV substation at Sharan with transformer capacity of 10 MVA and construction of 110 kV line from Ghazni to Sharan with a length of about 56 km
(ii) erection of 110/20 kV substation at Paktika with transformer capacity of 10 MVA and construction of 110 kV line from Gelan to Paktika with a length of about 60 km.

The required CAPEX is estimated at $18.2m. The single-line diagram is given in **Annex 8.2.26-3**.

P_25_B						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Ghazni	110kV	1			0.5	m$
new substation Sharan	110kV	2			3.3	m$
transformer Sharan	110/20kV	1	10		0.2	m$
expansion substation Gelan	110kV	1			0.5	m$
new substation Paktika	110kV	2			3.3	m$
transformer Paktika	110/20kV	1	10		0.2	m$
110kV line Ghazni - Sharan	1x3x1xACSR185			54	6.5	m$
110kV line Gelan - Paktika	1x3x1xACSR185			30	3.6	m$
Subtotal P_25_B					18.2	m$

Table 8.2.26-5: Additional CAPEX for power system in Paktika up to 2020

<u>Stage C up to 2025:</u>
In the period between 2020 and 2025, no CAPEX will be required for the Paktika transmission network to meet load growth.

<u>Stage D up to 2032:</u>
To meet load growth up to2032, the following additional transformers must be installed:

(i) one additional transformer at Sharan substation with a capacity of 10 MVA
(ii) one additional transformer at Paktika substation with a capacity of 10 MVA.

This will require a CAPEX of 1.5m$ and the single-line diagram for network development up to 2032 is given in **Annex 8.2.26-5**.

P_25_D						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Sharan	110kV	1			0.5	m$
transformer Sharan	110/20kV	1	10		0.2	m$
expansion substation Paktika	110kV	1			0.5	m$
transformer Paktika	110/20kV	1	10		0.2	m$
Subtotal P_25_D					1.5	m$

Table 8.2.26-6: Additional CAPEX for power system in Paktika up to 2032

8.2.27 Panjshir

8.2.27.1 Existing system

Panjshir province extends along the Darya-ye Panjshir valley. Currently, there is no power supply from the national grid.

8.2.27.2 Network expansion

According to the demand forecast, it is expected that this will be significant from 2020 on.

	Load and load forecast for Panjshir						
Year	2010	2011	2012	2015	2020	2025	2032
Population [Thousand]	141.4	143.7					
No of Households [Thousand]	14.1	14.4	14.7	15.6	17.2	18.9	21.4
Connection rate [%]	0.0	0.0	0.0	10.0	35.0	53.3	65.0
Gross Electricity Demand [GWh]	0.0	0.0	0.0	0.8	9.9	26.0	50.3
Net Electricity Demand [GWh]	0.0	0.0	0.0	0.5	7.4	19.9	39.2
Peak Demand [MW]	0.0	0.0	0.0	0.2	2.1	5.4	9.6

Table 8.2.27-1: Load and load forecast for Panjshir

There is no expected concentrated load center, so we propose constructing a 110 kV line along the valley to give the opportunity to drop down to various locations. For modeling and further calculations and cost estimates, we assume the load at a possible substation at Rukha.

Further load centers for Panjshir	Latitude N	Longitude E	
Rukha	35°16'15"N	69°28'30"E	*

* Substation coordinates estimated from map

Table 8.2.27-2: Further load centers for Panjshir

A small size of transformer with 4 MVA has been selected to allow distributed use of the transformer along the transmission line.

		Existing and further transformer capacity [MVA] Panjshir					
		2011	2012	2015	2020	2025	2032
Rukha	1 x 4				4.0	4.0	4.0
	1 x 4					4.0	4.0
	2 x 4						8.0
Total		0	0	0	4	8	16

Table 8.2.27-3: Existing and further transformer capacity [MVA] for Panjshir

	Existing and further load at substation level [MW] for Panjshir						
		2011	2012	2015	2020	2025	2032
Rukha					2.1	2.7	2.4
						2.7	2.4
							4.8
Total		0.0	0.0	0.0	2.1	5.4	9.6

Table 8.2.27-4: Existing and further load at substation level [MW] for Panjshir

8.2.27.3 Overview

Staged development of the transmission network in Panjshir (T_27) is described in the following and total CAPEX is estimated at about $12.8m. Network integration of Gulbahar HPP will require a CAPEX of $11.4m.

<u>Stage A up to 2015:</u>
Network development depends on erection of the substations in Parwan and Kapisa provinces and, for the period up to 2015, no CAPEX is expected for Panjshir province.

<u>Stage B up to 2020:</u>
For the period 2015 to 2020, the

(i) erection of 110 kV substation at Gullah with interbus transformer 220/110 kV
(ii) erection of 110/20 kV substation at Rukha with transformer capacity 4 MVA

will be possible.

CAPEX for expansion Stage B is estimated at about $10.9m and the single-line diagram is given in **Annex 8.2.27-3**.

P_27_B Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Gulbahar	220kV	1			0.9	m$
new substation Gulbahar	110kV	2			3.3	m$
interbus transformer Gulbahar	220/110kV	1	16		0.3	m$
new substation Rukha	110kV	2			3.3	m$
transformer Rukha	110/20kV	1	4		0.1	m$
110kV line Gulbahar - Rukha	110kV			25	3.0	m$
Subtotal P_27_B					10.9	m$

Table 8.2.27-5: Additional CAPEX for power system in Panjshir up to 2020

<u>Stage C up to 2025:</u>
To meet load growth up to 2025, an

(i) additional transformer 110/20 kV with a capacity of 4 MVA is required in Rukha or along the transmission line.

CAPEX will be about $0.6m and the single-line diagram for Panjshir up to 2025 is given in **Annex 8.2.27-4**.

P_27_C Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Rukha	110kV	1			0.5	m$
transformer Rukha	110/20kV	1	4		0.1	m$
Subtotal P_27_C					0.6	m$

Table 8.2.27-6: Additional CAPEX for power system in Panjshir up to 2025

Stage D up to 2032:
To meet load growth up to 2032,

(i) two additional transformers 110/20 kV each with a capacity of 4 MVA are required in Rukha or along the transmission line.

CAPEX will be about $1.2m.

P_27_D Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Rukha	110kV	2			1.1	m$
transformer Rukha	110/20kV	2	4		0.2	m$
Subtotal P_27_D					1.2	m$

Table 8.2.27-7: Additional CAPEX for power system in Panjshir up to 2032

The proposed site for Gulbahar hydropower plant is in Panjshir province and network integration will require the construction of a

(i) new 220 kV substation at Gulbahar HPP with step-up transformers for the generation units and a transmission line from Gulbahar HPP to Gulbahar substation with a length of about 5 km.

CAPEX for network integration of Gulbahar HPP (GN_08) will be $11.4m and the single line diagram for the network is given in Annex 8.2.27-5.

G_08_D Measure	Additional CAPEX up to 2032 Type	No	[MVA]	[km]	Cost	
new substation Gulbahar	220kV	5			7.4	m$
transformer Gulbahar	220/20kV	4	37.5		3.0	m$
220kV line Gulbahar HPP - Gulbahar	220kV			5	1.0	m$
Subtotal G_08_D					11.4	m$

Table 8.2.27-8: Additional CAPEX for power system in Panjshir up to 2032

8.2.28 Parwan

8.2.28.1 Existing system

Parwan province is located to the north of Kabul, but already south of Salang Pass. The region is crossed by the 220 kV double-circuit line from Pul-e-Chomri to Chimtala.
Currently, there is no substation along this line feeding the province.

8.2.28.2 Network expansion

The demand forecast for Parwan province, shown in Table 8.2.28-1, indicates a peak load of 65 MW up to 2032 and a connection rate of households of 82.5%.

	Load and load forecast for Parwan						
Year	2010	2011	2012	2015	2020	2025	2032
Population [Thousand]	610.3	620.9					
No of Households [Thousand]	64.6	65.9	67.2	71.3	78.7	86.6	97.9
Connection rate [%]	11.7	14.2	21.8	44.7	66.0	76.0	82.5
Gross Electricity Demand [GWh]	12.6	17.4	29.6	77.0	157.4	247.9	341.8
Net Electricity Demand [GWh]	8.7	12.0	20.6	54.9	116.9	189.1	266.4
Peak Demand [MW]	2.6	3.6	6.1	16.0	32.7	51.5	65.0

Table 8.2.28-1: Load and load forecast for Parwan

The load center in Parwan province is the region around Charikar along the A76 road and the valleys to Shipar Pass along the A77 road. The tentative locations of further substations were taken from the map as listed in Table 8.2.28-2 below.

Further load centers for Parwan	Latitude N	Longitude E	
Charikar	35° 0'40"	69° 9'30"E	*
Ghorband	34°59'20"N	68°43'10"E	*

* Substation coordinates estimated from map

Table 8.2.28-2: Further load centers for Parwan

The main bulk substation will be located in Charikar 220/20 kV with loop-in of the existing lines coming from the Salang Pass going to Chimtala. A further substation at Ghorband will be fed from Charikar via a 220 kV line. A 110 kV line will be sufficient for the load along the valley, but this voltage level is not planned at Charikar substation. Transformer capacity and loading for the new transformers are given in Table 8.2.28-3 and Table 8.2.28-4.

	Existing and further transformer capacity [MVA] Parwan						
		2011	2012	2015	2020	2025	2032
Charikar	2 x 16		32.0	32.0	32.0	32.0	32.0
Charikar	2 x 16					32.0	32.0
Ghorband	1 x 16				16.0	16.0	16.0
Total		0	32	32	48.0	80	80

Table 8.2.28-3: Existing and further transformer capacity [MVA] for Parwan

	Existing and further load at substation level [MW] for Parwan						
		2011	2012	2015	2020	2025	2032
Charikar			6.1	16.0	21.8	20.6	26.0
Charikar						20.6	26.0
Ghorband					10.9	10.3	13.0
Total		0.0	6.1	16.0	32.7	51.5	65.0

Table 8.2.28-4: Existing and further load at substation level [MW] for Parwan

Charikar substation will be the connection point for the power supply to Panjshir and Kapisa provinces. Furthermore, the future Golbahar hydropower plant may be connected to Charikar via Golbahar Town. The Kabul New City project will result in an expansion of Kabul to the north. The power supply from Charikar substation is proposed in this project.

8.2.28.3 Overview

Transmission network development for Parwan province can be achieved in stages over the planning horizon as indicated below. Total CAPEX for development is estimated at about $18.1m.

<u>Stage A up to 2015:</u>
Currently, there is an ongoing project for

(i) erection of substation 220/20 kV at Charikar with two transformers 16 MVA each.

CAPEX for Stage A is estimated at $8.5m.

P_28_A						
Measure	Type	No	[MVA]	[km]	Cost	
new substation Gharikar	220kV	6			7.8	m$
transformer Gharikar	220/20kV	2	16		0.7	m$
Subtotal P_28_A					8.5	m$

Table 8.2.28-5: CAPEX for power system in Parwan up to 2015

The single-line diagram for Stage A development is given in **Annex 8.2.28-2**.

<u>Stage B up to 2020:</u>
In Stage B, the transmission network in Parwan will be expanded by

(i) erection of substation 220/20 kV at Ghorband with transformer 16 MVA and 220 kV transmission line from Charikar to Ghorband.

Capital expenditure for this measure is estimated at $7.2m.

P_28_B						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Charikar	220kV	1			0.9	m$
new substation Ghorband	220kV	2			6.0	m$
transformer Ghorband	220/20kV	1	16		0.3	m$
Subtotal P_28_B					7.2	m$

Table 8.2.28-6: Additional CAPEX for power system in Parwan up to 2020

The single-line diagram resulting from this installation is given in **Annex 8.2.28-3** and also includes the expansion required for connection of Kapisa province. The measures and CAPEX for connection of Kapisa province are discussed in section 8.2.16.

<u>Stage C up to 2025:</u>
To meet load growth in the province, it is necessary to install

(i) two additional transformers220/20 kV at Charikar substation each with a capacity of 16 MVA.

CAPEX for Stage C is estimated at about $2.5m and the single-line diagram for the transmission system in Parwan, including Stage C development, is given in **Annex 8.2.28-4**.

P_28_C						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Charikar	220kV	2			1.8	m$
transformer Charikar	220/20kV	2	16		0.7	m$
Subtotal P_28_C					2.5	m$

Table 8.2.28-7: Additional CAPEX for power system in Parwan up to 2025

<u>Stage D up to 2032:</u>
Between 2025 and 2032, no additional measures for transmission system expansion are required in Parwan province.

8.2.29 Samangan

8.2.29.1 Existing system

The only load center in Samangan province, Aybak, is connected to the Afghan grid by a 20 kV line to Pul-e-Chomri substation. The connection rate was reported as 21% in 2011. The province is crossed by the 220 kV double-circuit line from Naibabad to Pul-e-Chomri.

Existing load centers for Samangan	Latitude N	Longitude E	
Aybak	36°16'40"N	68° 1'40"	*

* Substation coordinates estimated from map

Table 8.2.29-1: Existing load centers for Samangan

The existing transmission system configuration is given in **Annex 8.2.29-1**.

8.2.29.2 Network expansion

According to the demand forecast, peak load in Samangan province will increase to about 38 MW by 2032, as given in Table 8.2.29-2.

	Load and load forecast for Samangan						
Year	2010	2011	2012	2015	2020	2025	2032
Population [Thousand]	356.3	362.5					
No of Households [Thousand]	37.4	38.1	38.9	41.3	45.6	50.2	56.7
Connection rate [%]	18.1	20.9	27.4	47.0	66.0	76.0	82.5
Gross Electricity Demand [GWh]	11.6	14.7	21.2	47.8	91.1	143.6	197.9
Net Electricity Demand [GWh]	8.0	10.2	14.7	34.1	67.7	109.5	154.3
Peak Demand [MW]	2.4	3.1	4.4	9.9	18.9	29.8	37.7

Table 8.2.29-2: Load and load forecast for Samangan

Additional load centers are to the south of Aybak up to Khurram and in a valley to the southwest of Samangan where the proposed Dara-i-Suf power plant is located.

Further load centers for Samangan	Latitude N	Longitude E	
Khurram	35°55'50"	68° 0'30"	*
Dara-i-Suf	35°39'60"	67°14'0"	*

* Substation coordinates estimated from map

Table 8.2.29-3: Further load centers for Samangan

In the near future, a new substation at Aybak, looping into the 220 kV line Naibabad-Pul-e-Chomri, will be constructed.

Aybak substation is planned to be constructed as a 220/20 kV substation. The distance between Aybak and Khurram is about 40 km. It must be checked whether a voltage level of 20 kV will be sufficient for power supply to the valley south of Aybak to Khurram.

Dara-i-Suf is the proposed location of a new coal-fired power plant and the power supply in that area will be established in line with construction of the power plant and the related network connection.

The transformers proposed for power supply to the existing and new load centers and the loading is given in Table 8.2.29-4 and Table 8.2.29-5.

		Existing and further transformer capacity [MVA] Samangan					
		2011	2012	2015	2020	2025	2032
Aybak	1 x 16		16.0	16.0	16.0	16.0	16.0
Aybak	1 x 16					16.0	16.0
Khurram							
Dara-i-Suf	1 x 10			10.0	10.0	10.0	10.0
Dara-i-Suf	1 x 10				10.0	10.0	10.0
Total		0	16	26	36	52	52

Table 8.2.29-4: Existing and further transformer capacity [MVA] for Samangan

		Existing and further load at substation level [MW] for Samangan					
		2011	2012	2015	2020	2025	2032
Aybak		3.1	4.4	4.9	6.7	7.3	9.3
Aybak						7.3	9.3
Khurram	*			1.2	1.7	3.7	4.6
Dara-i-Suf				3.8	5.3	5.7	7.2
Dara-i-Suf					5.3	5.7	7.2
Total		3.1	4.4	9.9	18.9	29.8	37.7

* Khurram will be served from Aybak. Estimated 20% of load of Aybak

Table 8.2.29-5: Existing and further load at substation level [MW] for Samangan

8.2.29.3 Overview

The proposed staged development of the transmission network for Samangan province is discussed in the following chapter. Total CAPEX estimated for transmission system development will add up to $9.5m. Network integration of the new coal-fired power plant at Dara-i-Suf will amount to $94.5m.

Stage A up to 2015:
In the first development Stage A, the

(i) erection of new substation 220/20 kV at Aybak with transformer 16 MVA and loop-in of the existing 220 kV line from Naibabad to Pul-e-Chomri
(ii) expansion of substation 110 kV at Dara-i-Suf and installation of one transformer 110/20 kV with 10 MVA capacity

is planned. It is expected that, for the construction site of the new power plant at Dara-i-Suf, an independent power supply will be installed by the power plant contractor and that it will be possible to provide a power supply from the construction site.
The required capital expenditure for Stage A of network development in Samangan province is estimated at about $7.6m.

P_29_A						
Measure	Type	No	[MVA]	[km]	Cost	
new substation Aybak	220kV	3			6.5	m$
transformer Aybak	220/20kV	1	16		0.3	m$
expansion substation Dara-i-Suf	110kV	1			0.5	m$
transformer Dara-i-Suf	110/20kV	1	10		0.2	m$
Subtotal P_29_A					7.6	m$

Table 8.2.29-6: CAPEX for power system in Samangan up to 2015

The single-line diagram for the transmission network configuration for Samangan province up to 2015 is given in **Annex 8.2.29-2**.

Stage B up to 2020:
To meet load growth up to 2020, an

(i) additional transformer 10 MVA at Dara-i-Suf

is planned. Capital expenditure will be about $0.7m and the single-line diagram for the resulting system is given in **Annex 8.2.19-3**.

P_29_B						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Dara-i-Suf	110kV	1			0.5	m$
transformer Dara-i-Suf	110/20kV	1	10		0.2	m$
Subtotal P_29_B					0.7	m$

Table 8.2.29-7: Additional CAPEX for power system in Samangan up to 2020

Stage C up to 2025:
To meet load growth up to 2025, an

(i) Additional transformer 16 MVA at Aybak

is planned. Capital expenditure will be about 1.2m$ and the single-line diagram for the resulting system is given in **Annex 8.2.19-4**.

P_29_C						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Aybak	220kV	1			0.9	m$
transformer Aybak	220/20kV	1	16		0.3	m$
Subtotal P_29_C					1.2	m$

Table 8.2.29-8: Additional CAPEX for power system in Samangan up to 2025

<u>Stage D up to 2032:</u>
In the period 2025 to 2032, no additional CAPEX on development of the transmission network for supplying the loads will be required.

For network integration of the coal-fired power plant at Dara-i-Suf, we have included

(i) Erection of 500 kV substation at Dara-i-Suf TPP with generator step-up transformer of four times 240 MVA
(ii) Construction of 500 kV transmission line from Dara-i-Suf to Ishpushta

for the network development. The required CAPEX for network integration of Dara-i-Suf power plant is estimated at about $124.2m and the resulting transmission network configuration for Samangan is given in **Annex 8.2.29-5**.

G_23_D	Additional CAPEX up to 2032					
Measure	Type	No	[MVA]	[km]	Cost	
new substation Dara-i-Suf	500kV	5			21.3	m$
transformer Gulbahar	500/20kV	4	240		18.2	m$
expansion substation Ishpushta	500kV	1			0.0	m$
500kV line Data-i-Suf TPP - Ishpushta	2x3x3xACSR400			110	84.6	m$
Subtotal G_23_D					124.2	m$

Table 8.2.29-9: CAPEX for network integration of Dara-i-Suf TPP up to 2032

8.2.30 Sar-e Pol

8.2.30.1 Existing system

Currently, Sar-e Pol province is served by only one 110 kV substation at Sar-e Pol with an installed transformer capacity of 2x16 MVA. Sar-e Pol substation is connected to Sheberghan via a 110 kV single-circuit line. As already mentioned in section 8.2.8, the voltage drop at Andkhoy and Sheberghan is currently dramatically high and even the already installed loads in Sar-e Pol cannot be supplied.

Existing load centers for Sar-e Pol	Latitude N	Longitude E	
Sar-e Pul	36°12'50"	67° 8'46.3"	*

* Substation coordinates estimated from map

Table 8.2.30-1: Existing load centers for Sar-e Pol

The single-line diagram of the current system in Sar-e Pol is given in **Annex 8.2.30-1**.

8.2.30.2 Network expansion

Upon implementation of the TKM-AFG interconnection project, the voltage level at Sheberghan will be improved and it will be possible to serve existing loads and meet future expected load growth. The load according the demand forecast is given in the following table:

	Load and load forecast for Sar-e Pol						
Year	2010	2011	2012	2015	2020	2025	2032
Population [Thousand]	514.1	522.9					
No of Households [Thousand]	54.0	55.1	56.2	59.6	65.8	72.5	81.9
Connection rate [%]	10.4	11.4	19.5	43.8	66.0	76.0	82.5
Gross Electricity Demand [GWh]	12.3	14.8	26.4	70.1	131.6	207.4	285.9
Net Electricity Demand [GWh]	8.5	10.2	18.4	49.9	97.8	158.2	222.9
Peak Demand [MW]	2.6	3.1	5.5	14.5	27.3	43.0	54.4

Table 8.2.30-2: Load and load forecast for Sar-e Pol

In addition to the load center at Sar-e Pol town, there are other populated areas in the valleys south of Sar-e Pol town. Tentative positioning of a possible substation leads to the following additional load centers in Sar-e Pol province:

Further load centers for Sar-e Pol	Latitude N	Longitude E	
Tokzar	35°58'17"	66°25'56"	*
Qazaq	35°53'20"	66° 8'51"	*
Jarghan	35°53'40"	65°55'10"	*

* Substation coordinates estimated from map

Table 8.2.30-3: Further load centers for Sar-e Pol

To serve the loads to the south of Sar-e Pol, network expansion on the 110 kV radial from Sar-e Pol is proposed. In a first step, expansion could be by connection of the load center at Tokzar by 2015 and, in a next step, by connection of the load centers at Qazaq and Jarghan by 2020.

The existing and future transformer capacity as given in Table 8.2.30-4 will cope with the expected load growth in that province up to 2032.

		Existing and further transformer capacity [MVA] Sar-e Pol					
		2011	2012	2015	2020	2025	2032
Sar-e Pul	2 x 16	32.0	32.0	32.0	32.0	32.0	32.0
Sar-e Pul	1 x 16						16.0
Tokzar	1 x 10			10.0	10.0	10.0	10.0
Qazaq	1 x 10				10.0	10.0	10.0
Jarghan	1 x 10				10.0	10.0	10.0
Total		32	32	42	62	62	78

Table 8.2.30-4: Existing and further transformer capacity [MVA] for Sar-e Pol

Growth of the loads connected to the existing and new substations is expected according to the following table:

		Existing and further load at substation level [MW] for Sar-e Pol					
		2011	2012	2015	2020	2025	2032
Sar-e Pul		3.1	5.5	11.1	14.1	22.2	22.3
Sar-e Pul							11.2
Tokzar				3.5	4.4	6.9	7.0
Qazaq					4.4	6.9	7.0
Jarghan					4.4	6.9	7.0
Total		3.1	5.5	14.5	27.3	43.0	54.4

Table 8.2.30-5: Existing and further load at substation level [MW] for Sar-e Pol

8.2.30.3 Overview

To serve the increasing loads in Sar -e Pol province, additional load centers will be connected to the transmission system in the various stages of development. Total CAPEX for network development in Sar-e Pol province is estimated at $33.3m.

Stage A up to 2015:
In Stage A, an additional load center will be connected to the grid by construction of a

(i) new substation 110/20 kV at Tokzar with transformer 110/20 kV with a capacity of 10 MVA and 110 kV transmission line from Sar-e Pol to Tokzar with a length of 55 km.

Capital expenditure for Stage A is estimated at about $10.6m. **Annex 8.2.30-2** shows the single-line diagram for expansion up to 2015.

P_30_A						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Sar-e Pol	110kV	1			0.5	m$
new substation Tokzar	110kV	2			3.3	m$
transformer Tokzar	110/20kV	1	10		0.2	m$
110kV line Sar-e Pol - Tokzar	1x3x1xACSR185			55	6.6	m$
Subtotal P_30_A					10.6	m$

Table 8.2.30-6: CAPEX for power system in Sar-e Pol up to 2015

<u>Stage B up to 2020:</u>
In the period between 2015 and 2020, two more load centers are proposed for connection to the network. The measures for Stage B are:

(i) erection of new substation 110/20 kV at Qazaq with 110/20 kV transformer with a capacity of 10 MVA and construction of 110 kV line from Sar-e Pol to Qazaq with a length of 55 km
(ii) erection of new substation 110/20 kV at Jarghan with 110/20 kV transformer with a capacity of 10 MVA and construction of 110 kV line from Sar-e Pol to Jarghan with a length of 55 km.

CAPEX for Stage B development is estimated at $21.3m and the single-line diagram is given in **Annex 8.2.30-3**.

P_30_B						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Sar-e Pol	110kV	2			1.1	m$
new substation Qazaq	110kV	2			3.3	m$
transformer Qazaq	110/20kV	1	10		0.2	m$
new substation Jarghan	110kV	2			3.3	m$
transformer Jarghan	110/20kV	1	10		0.2	m$
110kV line Sar-e Pol - Qazaq	1x3x1xACSR185			55	6.6	m$
110kV line Sar-e Pol - Jarghan	1x3x1xACSR185			55	6.6	m$
Subtotal P_30_B					21.3	m$

Table 8.2.30-7: Additional CAPEX for power system in Sar-e Pol up to 2020

<u>Stage C up to 2025:</u>
For Stage C, no additional CAPEX on the Sar-e Pol transmission network is required.

<u>Stage D up to 2032:</u>
To meet load growth, it is proposed to install an

(i) additional transformer 110/20 kV at Sar-e Pol with a capacity of 16 MVA.

The required CAPEX will be about $1.4m and the single-line diagram is given in **Annex 8.2.30-5**.

P_30_D						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Sar-e Pol	110kV	2			1.1	m$
transformer Sar-e Pol	110/20kV	1	16		0.3	m$
Subtotal P_30_D					1.4	m$

Table 8.2.30-8: Additional CAPEX for power system in Sar-e Pol up to 2032

8.2.31 Takhar

8.2.31.1 Existing system

Currently, there is no interconnection between Takhar province and the transmission system. Only small self-generation systems for local power supply are installed. Records show a connection rate of households of about 4% for 2011. Takhar province is located in the northeast of Afghanistan at the border with Tajikistan. Kunduz province, the neighboring province to the west of Takhar, is already connected to the national grid.

8.2.31.2 Network expansion

The demand forecast considers an increase in the connection rate to 70% up to 2032 and a resulting peak demand of about 84 MW. The expected growth of demand in Takhar province is given in Table 8.2.31-1 below.

	Load and load forecast for Takhar						
Year	**2010**	**2011**	**2012**	**2015**	**2020**	**2025**	**2032**
Population [Thousand]	901.9	917.7					
No of Households [Thousand]	97.9	99.9	101.9	108.1	119.4	131.4	148.5
Connection rate [%]	1.7	3.8	8.9	24.3	50.0	58.3	70.0
Gross Electricity Demand [GWh]	1.1	2.1	6.0	26.2	140.6	235.3	439.4
Net Electricity Demand [GWh]	0.8	1.4	4.2	18.6	104.4	179.5	342.5
Peak Demand [MW]	0.2	0.4	1.2	5.4	29.2	48.8	83.6

Table 8.2.31-1: Load and load forecast for Takhar

The populated areas are around Taluqan in the center of the province and in the north around Rustaq and Cha Ab. Furthermore, there are two valleys in the south along the River Darya-ye Bagi (Afaqi) and up to the area around Ashkamesh. The tentative locations of possible new load centers are given in Table 8.2.31-2.

Further load centers for Takhar	Latitude N	Longitude E	
Taluqan	36°44'15.42"	69°29'23.86"	*
Rustaq	37°7'20"	69°48'30"	**
Cha Ab	37°21'50"	69°45'5"	**
Afaqi	36°38'44"	69°21'25"	**
Ashkamesh	36°23'48"	69°18'20"	**

* Substation coordinates given by DABS (DBS_031)

** Substation coordinates estimated from map

Table 8.2.31-2: Further load centers for Takhar

Power supply to Takhar will be achieved by construction of a substation at Taluqan and a 220 kV line from the new 220 kV substation Kunduz 2 to Taluqan. This project is an ongoing project with ADB financing.

Connection of additional load centers at the 110 kV level will be possible starting from Taluqan substation. Up to 2020, connection of Rustaq and Afaqi is expected, followed by Cha Ab and Ashkamesh, which will be connected to Rustaq and Afaqi up to 2025.

Supply to Rustaq and Aha Ab may also be possible from a further power station at Kukcha or from a t-off from a further line Taluqan - Faizabad.

The timing of the installation of additional transformer capacity in Takhar province and the expected loading are given in the following tables:

	Existing and further transformer capacity [MVA] Takhar						
		2011	2012	2015	2020	2025	2032
Taluqan	1 x 16			16.0	16.0	16.0	16.0
Taluqan	1 x 16					16.0	16.0
Taluqan	1 x 16						16.0
Rustaq	1 x 16				16.0	16.0	16.0
Cha Ab	1 x 16					16.0	16.0
Afaqi	1 x 16				16.0	16.0	16.0
Ashkamesh	1 x 16					16.0	16.0
Total		0	0	16	48	96	112

Table 8.2.31-3: Existing and further transformer capacity [MVA] for Takhar

	Existing and further load at substation level [MW] for Takhar						
		2011	2012	2015	2020	2025	2032
Taluqan				5.4	14.6	8.1	11.9
Taluqan						8.1	11.9
Taluqan							11.9
Rustaq					7.3	8.1	11.9
Cha Ab						8.1	11.9
Afaqi					7.3	8.1	11.9
Ashkamesh						8.1	11.9
Total		0.0	0.0	5.4	29.2	48.8	83.6

Table 8.2.31-4: Existing and further load at substation level [MW] for Takhar

8.2.31.3 Overview

Total CAPEX for development of the transmission network in Takhar province (P_31) is estimated at about $67.7m, allowing for network development according to the following stages:

<u>Stage A up to 2015:</u>

(i) expansion of new substation Kunduz 2 with one line feeder,
(ii) erection of new substation 220/110/20 kV at Taluqan with one interbus transformer 50 MVA and one transformer 16 MVA and

(iii) construction of 220 kV line Kunduz 2 to Taluqan type 1x3x2xACSR300 with a length of about 66 km.

Network development up to 2015 is given as a single-line diagram in **Annex 8.2.31-2** and the expected CAPEX for Stage A is about $30m, as given in Table 8.2.31-5 below.

P_31_A						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Kunduz 2	220kV	1			0.9	m$
new substation Taluqan	220kV	2			6.0	m$
new substation Taluqan	110kV	2			3.3	m$
interbus transformer Taluqan	220/110kV	1	50		1.0	m$
transformer Taluqan	110/20kV	1	16		0.3	m$
220kV line Kunduz - Taluqan	1x3x2xACSR300			66	18.5	m$
Subtotal P_31_A					30.0	m$

Table 8.2.31-5: CAPEX for power system in Takhar up to 2015

Stage B up to 2020:

Up to 2020, development of the 110 kV network in Takhar is expected by

(i) erection of new substation 110/20 kV at Rustaq with transformer 16 MVA and construction of 110 kV line Taluqan to Rustaq with a length of about 60 km

(ii) erection of new substation 110/20 kV at Afaqi with transformer 16 MVA and construction of 110 kV line Taluqan to Afaqi with a length of about 20 km.

The network configuration in Takhar province for 2020 is given in **Annex 8.2.31-3**. The estimated cost of network development in Stage B is $17.9m, as given in the table below.

P_31_B						
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Taluqan	110kV	2			1.1	m$
new substation Rustaq	110kV	2			3.3	m$
transformer Rustaq	110/20kV	1	16		0.3	m$
new substation Afaqi	110kV	2			3.3	m$
transformer Afaqi	110/20kV	1	16		0.3	m$
110kV line Taluqan - Rustaq	1x3x1xACSR185			60	7.2	m$
110kV line Taluqan - Afaqi	1x3x1xACSR185			20	2.4	m$
Subtotal P_31_B					17.9	m$

Table 8.2.31-6: Additional CAPEX for power system in Takhar up to 2020

Stage C up to 2025:

In Stage C, further expansion of the transmission system in Takhar province will be necessary with

(i) additional transformer capacity at Taluqan with interbus transformer 220/110 kV with capacity of 50 MVA and transformer 110/20 kV with capacity of 16 MVA

(ii) erection of Cha Ab substation with transformer 110/20 kV 16 MVA and 110 kV line from Rustaq to Cha Ab with a length of about 30 km

(iii) erection of Ashkamesh substation with transformer 110/20 kV 16 MVA and 110 kV line from Afaqi to Ashkamesh with a length of about 30 km.

CAPEX for Stage C development is estimated at 18.9m$, as given in Table 8.2.31-7 and network development is given in **Annex 8.2.31-4**.

P_31_C Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Taluqan	220kV	1			0.9	m$
expansion substation Taluqan	110kV	2			1.1	m$
interbus transformer Taluqan	220/110kV	1	50		1.0	m$
transformer Taluqan	110/20kV	1	16		0.3	m$
expansion substation Rustaq	110kV	1			0.5	m$
expansion substation Afaqi	110kV	1			0.5	m$
new substation Cha Ab	110kV	2			3.3	m$
transformer Cha Ab	110/20kV	1	16		0.3	m$
new substation Ashkamesh	110kV	2			3.3	m$
transformer Ashkamesh	110/20kV	1	16		0.3	m$
110kV line Rustaq - Cha Ab	1x3x1xACSR185			30	3.6	m$
110kV line Afaqi - Ashkamesh	1x3x1xACSR185			30	3.6	m$
Subtotal P_31_C					18.9	m$

Table 8.2.31-7: Additional CAPEX for power system in Takhar up to 2025

<ins>Stage D up to 2032:</ins>
Stage D of network development in Takhar province will require only

(i) an additional transformer at Taluqan.

Capital expenditure, therefore, is estimated at $0.9m and network development is given in the single-line diagram in **Annex 8.2.31-5**.

P_31_D Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Taluqan	110kV	1			0.5	m$
transformer Taluqan	110/20kV	1	16		0.3	m$
Subtotal P_31_D					0.9	m$

Table 8.2.31-8: Additional CAPEX for power system in Takhar up to 2032

8.2.32 Uruzgan

8.2.32.1 Existing system

Uruzgan province is located in the center of Afghanistan and is currently not connected to the national grid of Afghanistan.

8.2.32.2 Network expansion

According to the demand forecast, peak load in 2032 in Uruzgan province is expected to be 28 MW and the connection rate will increase to 70% of households.

	Load and load forecast for Uruzgan						
Year	2010	2011	2012	2015	2020	2025	2032
Population [Thousand]	322.6	328.0					
No of Households [Thousand]	32.9	33.4	34.1	36.2	39.9	43.9	49.6
Connection rate [%]	2.1	2.4	7.7	23.6	50.0	58.3	70.0
Gross Electricity Demand [GWh]	0.0	0.4	2.0	11.8	47.0	78.7	146.9
Net Electricity Demand [GWh]	0.0	0.3	1.4	8.4	34.9	60.0	114.5
Peak Demand [MW]	0.0	0.1	0.4	2.5	9.8	16.3	28.0

Table 8.2.32-1: Load and load forecast for Uruzgan

The inhabited areas in Uruzgan province extend along the River Helmand and its tributaries. Therefore, the load centers are expected to be in the western part of the province around Tirin Kot and along the river from Olambagh to Kajaki. With regard to the eastern part, the major load is expected around Uruzgan city.

Further load centers for Uruzgan	Latitude N	Longitude E	
Uruzgan	32°55'20"	66°38'30"	**
Tirin Kot	32°39'10"	65°53'	**
Tandor	32°37'30"	65°30'	**
Olambagh	32°52'	65°30'	*

* According to generation expansion options received from DABS/MEW

** Substation coordinates estimated from map

Table 8.2.32-2: Further load centers for Uruzgan

The proposed transformer capacity at the new substations and the expected loading of the transformers are given in the following tables.

	Existing and further transformer capacity [MVA] Uruzgan						
		2011	2012	2015	2020	2025	2032
Uruzgan	1 x 10				10.0	10.0	10.0
Tirin Kot	1 x 10					10.0	10.0
Tandor	1 x 10				10.0	10.0	10.0
Olambagh	1 x 10						10.0
Total		0	0	0	20	30	40

Table 8.2.32-3: Existing and further transformer capacity [MVA] for Uruzgan

	Existing and further load at substation level [MW] for Uruzgan						
		2011	2012	2015	2020	2025	2032
Uruzgan					4.9	5.4	7.0
Tirin Kot						5.4	7.0
Tandor					4.9	5.4	7.0
Olambagh							7.0
Total		0.0	0.0	0.0	9.8	16.3	28.0

Table 8.2.32-4: Existing and further load at substation level [MW] for Uruzgan

Power supply to Uruzgan substation will be possible after erection of the NEPS to SEPS interconnector by 2020 with a 110 kV line from the new substation at Galat-e Gilzay in Zabul province. The western part up to Tini Kot will be supplied from Kajaki.

It will be possible to close the ring at the 110 kV level by construction of the line from Uruzgan to Tini Kot.

8.2.32.3 Overview

Development of the transmission network in Uruzgan will start in the period between 2015 and 2020 and further, staged implementation will require a CAPEX of about 34.9m$. At the end of the planning horizon, network integration of Olambagh HPP is expected (GN_12) and this will require a CAPEX of about $10.3m.

Stage A up to 2015:
No network development is possible in the first stage.

Stage B up to 2020:
For supplying the loads in Uruzgan, the following measures are proposed in Stage B:

(i) erection of new substation 110/20 kV at Uruzgan with transformer capacity of 10 MVA and construction of 110 kV line from Galat-e Gilzay to Uruzgan substation with a length of about 100 km
(ii) erection of new substation 110/20 kV at Tandor with transformer capacity of 10 MVA and construction of 110 kV line from Kajaki to Tandor with a length of about 50 km.

Capital expenditure for Stage B is estimated at $26.1m and the resulting network configuration is given in **Annex 8.2.32-3**.

P_32_B Measure	Type	No	[MVA]	[km]	Cost	
expansion subst. Galat-e Gilzay	110kV	1			0.5	m$
new substation Uruzgan	110kV	2			3.3	m$
transformer Uruzgan	110/20kV	1	10		0.2	m$
110kV line Galat-e G. - Uruzgan	1x3x1xACSR185			100	12.0	m$
expansion substation Kajaki	110kV	1			0.5	m$
new substation Tandor	110kV	2			3.3	m$
transformer Tandor	110/20kV	1	10		0.2	m$
110kV line Kajaki - Tandor	1x3x1xACSR185			50	6.0	m$
Subtotal P_32_B					26.1	m$

Table 8.2.32-5: Additional CAPEX for power system in Uruzgan up to 2020

Stage C up to 2025:
In the period 2020 to 2025, erection of a

(i) new substation 110/20 kV at Tirin Kot with transformer capacity of 10 MVA and construction of 110 kV line from Tandor to Tirin Kot with a length of about 40 km

is proposed. Capital expenditure will be about $8.8m and the single-line diagram for the transmission system is given in **Annex 8.2.32-4**.

P_32_C Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Tandor	110kV	1			0.5	m$
new substation Tirin Kot	110kV	2			3.3	m$
transformer Tirin Kot	110/20kV	1	10		0.2	m$
110kV line Tandor - Tirin Kot	1x3x1xACSR185			40	4.8	m$
Subtotal P_32_C					8.8	m$

Table 8.2.32-6: Additional CAPEX for power system in Uruzgan up to 2025

There is an option for closing the ring with 110 kV line Uruzgan to Tirin Kot with length of about 80 km

Stage D up to 2032:
For the period up to 2032, construction of Olambagh HPP is expected and it will be possible to supply the loads around Olambagh from the power plant at the 20 kV level. Therefore, no CAPEX is expected for the transmission system to meet further demand.

For network integration of Olambagh hydropower plant with a total capacity of 90 MW, the following measures are required (GN_12):

(i) erection of substation 110 kV at Olambagh with step-up transformer 110/20 kV for the generation units and construction of 110 kV transmission line from Olambagh to Tandor with a length of about 30 km.

Network integration of Olambagh HPP will require a CAPEX of about $10.3m.

G_12_D	Additional CAPEX up to 2032					
Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Tandor	110kV	1			0.5	m$
new substation Olambagh	110/20kV	4			3.7	m$
transformer Olambagh	110/20kV	3	40		2.5	m$
110kV line Olambagh - Tandor	1x3x1xACSR185			30	3.6	m$
Subtotal G_12_D					10.3	m$

Table 8.2.32-7: CAPEX for network integration of Olambagh HPP up to 2032

The single-line diagram of the resulting network in Uruzgan up to 2032 is given in **Annex 8.2.32-5**.

8.2.33 Wardak

8.2.33.1 Existing system

Currently, Wardak province is not supplied from the national transmission grid of Afghanistan. Only 4% of households were connected to the power supply from an isolated generation unit in 2011.

8.2.33.2 Network expansion

According the load forecast for the province, peak demand will increase to 47 MW in 2032 and the connection rate will reach 70%.

	Load and load forecast for Wardak						
Year	2010	2011	2012	2015	2020	2025	2032
Population [Thousand]	549.2	558.4					
No of Households [Thousand]	55.1	56.2	57.3	60.8	67.2	73.9	83.6
Connection rate [%]	0.0	4.0	9.1	24.4	50.0	58.3	70.0
Gross Electricity Demand [GWh]	3.0	5.3	12.3	37.4	101.8	162.4	247.5
Net Electricity Demand [GWh]	2.0	3.6	8.5	26.6	75.6	123.9	192.9
Peak Demand [MW]	0.6	1.1	2.6	7.8	21.1	33.7	47.1

Table 8.2.33-1: Load and load forecast for Wardak

Load centers are expected along the A1 ring road from Kabul to Kandahar and the crossing valley near Sayad Abad and the valley along the road from Kabul to Bamyan. Therefore, it is expected to have a substation at Sayad Abad along the new NEPS to SEPS interconnector and a substation at Maydan Shar in the valley to Bamyan.

Further load centers for Wardak	Latitude N	Longitude E	
Maydan Shar	34°26'30"	68°48'40"	*
Sayad Abad	34° 3'20"	68°44'50"	*

* Substation coordinates estimated from map

Table 8.2.33-2: Further load centers for Wardak

The transformer capacity expected to be installed in the new substations and the expected loading in the time horizon are given in the following Table 8.2.33-3 and Table 8.2.33-4.

		Existing and further transformer capacity [MVA] Wardak					
		2011	2012	2015	2020	2025	2032
Maydan Shar	1 x 16			16.0	16.0	16.0	16.0
Maydan Shar	1 x 16					16.0	16.0
Sayad Abad	1 x 16				16.0	16.0	16.0
Sayad Abad	1 x 16						16.0
Total		0	0	16	32	48	64

Table 8.2.33-3: Existing and further transformer capacity [MVA] for Wardak

	Existing and further load at substation level [MW] for Wardak						
		2011	2012	2015	2020	2025	2032
Maydan Shar				7.8	10.6	11.2	11.8
Maydan Shar						11.2	11.8
Sayad Abad					10.6	11.2	11.8
Sayad Abad							11.8
Total		0.0	0.0	7.8	21.1	33.7	47.1

Table 8.2.33-4: Existing and further load at substation level [MW] for Wardak

8.2.33.3 Overview

For staged development of the transmission system for power supply in Wardak province, (P_33) a total CAPEX of about $15.9m is estimated.

Stage A up to 2015:
With erection of the new substation at Arghandi south of Kabul, the

(i) routing of a 110 kV line to Maydan Shar, line length about 15 km and erection of 110 kV substation at Maydan Shar with transformer 16 MVA

will be possible.

This measure requires a CAPEX in Stage A of about $6.1m and the single-line diagram is given in **Annex 8.2.33-2**.

P_33_A Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Arghandi	110kV	1			0.5	m$
new substation Maydan Shar	110kV	2			3.3	m$
transformer Maydan Shar	110/20kV	1	16		0.3	m$
110kV line Arghandi - Maydan S.	1x3x1xACSR185			16	1.9	m$
Subtotal P_33_A					6.1	m$

Table 8.2.33-5: CAPEX for power system in Wardak up to 2015

Stage B up to 2020:
It is expected that the interconnection between NEPS and SEPS will be erected by 2020 and the measures and CAPEX were discussed in section 6.3.

For expansion of the power supply in Wardak province, the following will be required up to 2020:

(i) new substation 220 kV at Sayad Abad along the new NEPS to SEPS interconnector with transformer 220/20 kV and capacity of 16 MVA, located about 52 km from Arghandi.

For the cost estimate, it is assumed that the substation along the NEPS to SEP interconnector will be related only to the power supply for the region and the substations will be equipped already in the initial phase with feeders for looping in and out of both of the circuits of the interconnection line. The cost of Stage B expansion for Wardak province is estimated at about $7.7m. The single-line diagram for Stage B is given in **Annex 8.2.33-3**.

P_33_B Measure	Type	No	[MVA]	[km]	Cost	
new substation Sayad Abad	220kV	5			7.4	m$
transformer Sayad Abad	220/20kV	1	16		0.3	m$
Subtotal P_33_B					7.7	m$

Table 8.2.33-6: Additional CAPEX for power system in Wardak up to 2020

Stage C up to 2025:
To meet load growth in Wardak province up to 2025, an

(i) additional transformer at Maydan Shar 110/20 kV with a capacity of 16 MVA

will be required. CAPEX will be about $0.9m and Annex 8.2.33-4 presents the single-line diagram up to 2025.

P_33_C Measure	Type	No	[MVA]	[km]	Cost	
expansion subst. Maydan Shar	110kV	1			0.5	m$
transformer Maydan Shar	110/20kV	1	16		0.3	m$
Subtotal P_33_C					0.9	m$

Table 8.2.33-7: Additional CAPEX for power system in Wardak up to 2025

Stage D up to 2032:
Load growth in Wardak province up to 2032 will require the erection of an

(i) additional transformer at Sayad Abad 220/20 kV with a capacity of 16 MVA.

Capital expenditure will be about $1.2m.

P_33_D Measure	Type	No	[MVA]	[km]	Cost	
expansion substation Sayad Abad	220kV	1			0.9	m$
transformer Sayad Abad	220/20kV	1	16		0.3	m$
Subtotal P_33_D					1.2	m$

Additional CAPEX for power system in Wardak up to 2032

The single-line diagram for transmission network development in Wardak province up to 2032 is given in **Annex 8.2.33-5**.

8.2.34 Zabul

8.2.34.1 Existing system

Zabul province is located in the southeast of Afghanistan along the A1 ring road. Currently, Zabul province has no power supply from the national grid and about 8% of households had access to a power supply from local generation units in 2011.

8.2.34.2 Network expansion

In the planning horizon, demand in Zabul province will in increase to 25 MW and this will represent a connection rate of 70% of households.

	Load and load forecast for Zabul						
Year	2010	2011	2012	2015	2020	2025	2032
Population [Thousand]	279.8	284.6					
No of Households [Thousand]	28.7	29.3	29.9	31.7	35.0	38.5	43.5
Connection rate [%]	7.8	8.4	13.0	26.9	50.0	58.3	70.0
Gross Electricity Demand [GWh]	3.7	4.4	7.5	20.1	53.0	84.6	128.9
Net Electricity Demand [GWh]	2.5	3.0	5.2	14.3	39.4	64.5	100.5
Peak Demand [MW]	0.8	0.9	1.6	4.2	11.0	17.6	24.5

Table 8.2.34-1: Load and load forecast for Zabul

The load center is expected along the A1 ring road. Therefore, a substation is planned along the planned NEPS to SEPS interconnector. The substation is proposed to be located near Qalat-e Gilzay.

Further load centers for Zabul	Latitude N	Longitude E	
Qalat-e Gilzay	32° 6'20"	66°54'	*

* Substation coordinates estimated from map

Table 8.2.34-2: Further load centers for Zabul

The required transformer capacity to be installed at the new substation and the expected loading are given in the following tables.

		Existing and further transformer capacity [MVA] Zabul					
		2011	2012	2015	2020	2025	2032
Qalat-e Gilzay	1 x 16				16.0	16.0	16.0
Qalat-e Gilzay	1 x 16					16.0	16.0
Total		0	0	0	16	32	32

Table 8.2.34-3: Existing and further transformer capacity [MVA] for Zabul

	Existing and further load at substation level [MW] for Zabul						
		2011	2012	2015	2020	2025	2032
Qalat-e Gilzay					11.0	8.8	12.3
Qalat-e Gilzay						8.8	12.3
Total		0.0	0.0	0.0	11.0	17.6	24.5

Table 8.2.34-4: Existing and further load at substation level [MW] for Zabul

Because the population is not very concentrated, the 20 kV level seems not to be sufficient for distribution and the 110 kV level will be required for further development. Furthermore, Qalat-e Gilzay substation can used for feeding the substations in Uruzgan province at the 110 kV level.

8.2.34.3 Overview

Network development in Zabul province will be possible in line with erection of the interconnector from NEPS to SEPS. Total CAPEX for the transmission system in Zabul province is estimated at 14.4m$.

Stage A up to 2015:
In Stage A, no CAPEX on the transmission system in Zabul province is possible.

Stage B up to 2020:
For Stage B, the following development is proposed:

(i) erection of substation 220/110/20 kV at Qalat-e Gilzay with interbus transformer 220/110 kV capacity of 25 MVA and transformer 110/20 kV with a capacity of 16 MVA and loop-in of the 220 kV interconnector NEPS to SEPS.

CAPEX for these measures is estimated at $11.5m. The single-line diagram for network development up to 2020 is given in **Annex 8.2.34-3**.

P_34_B Measure	Type	No	[MVA]	[km]	Cost	
new substation Qalat-e Gilzay	220kV	5			7.4	m$
new substation Qalat-e Gilzay	110kV	2			3.3	m$
transformer Qalat-e Gilzay	220/110kV	1	25		0.5	m$
transformer Qalat-e Gilzay	220/20kV	1	16		0.3	m$
Subtotal P_34_B					11.5	m$

Table 8.2.34-5: Additional CAPEX for power system in Zabul up to 2020

Stage C up to 2025:
To meet load growth, an

(i) additional transformer 110/20 kV at Qalat-e Gilzay substation with a capacity of 16 MVA

will be required. Capital expenditure, therefore, is estimated at $0.9m. The single-line diagram is given in **Annex 8.2.34-4**.

P_34_C						
Measure	Type	No	[MVA]	[km]	Cost	
expansion subst. Qalat-e Gilzay	110kV	2			0.5	m$
transformer Qalat-e Gilzay	110/20kV	1	16		0.3	m$
Subtotal P_34_C					0.9	m$

Table 8.2.34-6:Additional CAPEX for power system in Zabul up to 2025

Stage D up to 2032:
For Stage D, an

(i) additional interbus transformer 220/110kV at Qalat-e Gilzay substation with a capacity of 25 MVA

will be required. Capital expenditure for Stage D is estimated at $2m and the resulting network development is given in **Annex 8.2.34-5**.

P_34_D						
Measure	Type	No	[MVA]	[km]	Cost	
expansion subst. Qalat-e Gilzay	220kV	1			0.9	m$
expansion subst. Qalat-e Gilzay	110kV	1			0.5	m$
transformer Qalat-e Gilzay	220/110kV	1	25		0.5	m$
Subtotal P_34_D					2.0	m$

Table 8.2.34-7: Additional CAPEX for power system in Zabul up to 2032

8.3 Additional Wheeling

In addition to Afghan national needs for transmission of energy to its internal load centers, the wheeling of energy through the territory of Afghanistan is under discussion by several committees and donors.

One option is a link between energy-rich Central Asia and South Asia. A second option is the support of hydropower-dominated countries during the winter season and the third option is the ongoing Turkmenistan - Afghanistan interconnection project.

Network expansion will support the following scenarios or will at least not undermine their possible development:

- expansion scenario for Turkmenistan - Afghanistan import
- expansion scenario for export to Pakistan
- expansion scenario for winter export to Tajikistan.

9. Environmental Impact and Social Safeguard Implications

9.1 Assessment of Environmental Impact

Environmental impacts related to power generation and energy infrastructure projects mainly concern emissions to air and noise, raw water use and possible water pollution, lost of fauna and flora habitats, and disturbance of the landscape. The evaluation of the significance of these impacts is the subject of an Environmental Impact Assessment to be done at a stage when all relevant design information and design requirements are available. This is applicable for the construction as well as for the operation of the stipulated projects.

The selected projects possess the potential to create significant environmental impacts on local and regional levels, and an assessment of their implications should outline which impacts require further attention and investigation in the upcoming project phases. Additionally, the environmental review should determine if any significant impacts could be identified that would prevent further project development.

Supplementary to the initial impact evaluation, recommendations for more detailed investigations and studies will be made for each group of projects, i.e. thermal power plants, hydropower plants and transmission lines.

The environmental impact evaluation was done by desktop research without a detailed knowledge of the local environmental baseline conditions and without having specifically needed technical design information, such as emission rates, noise limits or the exact project location.

9.1.1 Legislative framework

National EIA Legislation or Guideline
The Environmental Law of the Islamic Republic of Afghanistan, dated 2007, mandates that projects, plans, policies and activities require preliminary environmental impact screening to identify any potential adverse impacts or positive effects that they might have. If it is likely that these will have significant adverse effects on the environment, international best practices for execution of an environmental impact assessment (EIA) shall apply. It is emphasized that public consultation is needed for the development and implementation of industrial projects, such as power generation plants.

A specific Environmental Impact Assessment (EIA) Guideline is not in force at the time of the preparation of this Master Plan. The current existing Government’s regulation on environmental impact assessment is based on the Environmental Act of the Islamic Republic of Afghanistan (Gazette No. 912), dated 25 January, 2007.

International Safeguards

ADB’**s** environmental safeguards aim to ensure the environmental soundness and sustainability of projects, and to support the integration of environmental considerations into the project decision-making process. The Safeguard Policy Statement (SPS) requires borrowers to identify project impacts and assess their significance; examine alternatives; and prepare, implement, and monitor environmental management plans. The SPS requires borrowers to consult people likely to be affected by the project and disclose relevant information in a timely manner and in a form and in languages understandable to those being consulted.

Proposed projects are screened according to type, location, scale, and sensitivity and the magnitude of their potential environmental impacts, including direct, indirect, induced, and cumulative impacts.

Projects are classified into the following four categories:

Category A:
A proposed project is likely to have significant adverse environmental impacts that are irreversible, diverse, or unprecedented. These impacts may affect an area larger than the sites or facilities subject to physical works. An environmental impact assessment (EIA), including an environmental management plan (EMP), is required.

Category B:
The proposed project’s potential adverse environmental impacts are site-specific: few if any of them are irreversible, and in most cases mitigation measures can be designed more readily than for category A projects. An initial environmental examination (IEE), including an EMP, is required.

Category C:
A proposed project is likely to have minimal or no adverse environmental impacts. An EIA or IEE is not required, although environmental implications need to be investigated.

Category FI:
A proposed project involves the investment of ADB funds to or through a financial intermediary. The financial intermediary must apply and maintain an environmental and social management system, unless all of the financial intermediary's business activities have minimal or no environmental impacts or risks.

In **World Bank** operations, the Social and Environmental Assessment (SEA) plays a key role in ensuring that project options under consideration are sound and sustainable from an environmental point of view.

The relevant environmental and social policies are listed below:

- Environmental Assessment (OP 4.01)
- Environmental Action Plans (OP 4.02)

- Natural Habitats (OP 4.04)
- Water Resources Management (OP 4.07)
- Cultural Property (OP 4.11)
- Safety of Dams (OP/BP 4.37)

OP 4.01 is especially relevant from an environmental point of view because it provides one of the foundations for international best environmental impact assessment practices in the execution of an EIA.

9.1.2 Generic environmental baseline conditions

Climate

During winter, westerly winds usually bring moderate rainfall, while summers are dry and only in the extreme southeast do monsoon winds bring some rain. In winter, sometimes and especially in the north, snow down to the valleys is possible. The climate of the country's south corresponds to warmer subtropics where cultivation of date palms is possible, while the north belongs more to a temperate zone. In 2000, half the population suffered from one of the frequent severe droughts. Such droughts could become even more frequent in future as climate change could cause a decrease in precipitation and, especially in winter and spring, lead to the climate becoming more arid. For the south-east that is affected by monsoons, it is to be feared, though, that in summer rainfall will become significantly more variable because of additional atmospheric warming, and the Indian monsoon system is unstable. Of particular significance for the high proportion of rural population, agriculture could be affected negatively.

Ambient air quality

Dust and traffic emissions are the most serious air pollution problem in urban areas in Afghanistan. The dust problems have increased in recent years due to the drought and loss of protective vegetation. Emissions from cars and trucks are a significant health problem in the towns. Compared to traffic and residential heating, the present level of air pollution from thermal power plants is not a major health problem. Information on these concerns is not available for the country's rural areas but it is assumed that dust is likewise a problem, especially during the dry season. Emission from traffic is expected to be a problem along the major and highly frequented roads.

Flora and fauna

The vegetation varies depending on the fertility and humidity of the local soil, but is generally sparse. Near and around the perennial and seasonal rivers, the vegetation is fairly dense, with some plantations, a few trees, bushes and grassland. Further to the south-east across the plains and from Andkhoy northwards, the bush and cultivation thins out to grassland savannah and sandy desert without vegetation. From Sheberghan, the land becomes barren or cultivated, with semi-desert savannah before the Balkh River up to the outskirts of Mazar-e Sharif. Only in river valleys are there are patches of azonal vegetation. In the lowlands, all arable surfaces are cultivated and artificially irrigated or watered by rainfall. Biological diversity is low.

River basins, wetlands and lakes
Afghanistan can be divided into five principal river basins:

- Amu Darya
- Hari Rud
- Kabul
- Helmand and
- Farah Rud.

Except for Amu Darya, all the water available for utilization in Afghanistan originates inside the country's borders. In all cases, however, the rivers are to be classified as international watercourses because any use by Afghanistan may have an impact on water use and ecosystem functioning in downstream countries.

In the dry south-west of Afghanistan in the border area with Iran, Helmand, Khash Rud and Farah Rud have formed a large complex of wetlands and lakes – the Sistan wetlands. The wetland area varies significantly from year to year depending on the inflow of the main rivers. In years of high waters the wetlands can cover up to 4,000 km^2. The wetlands and lakes are of international value for biodiversity, in particular for migrating waterfowl. Since 1998 the water inflow to the wetlands has been drastically reduced. The cause of this is primarily a sequence of dry years, but water loss from upstream reservoirs and irrigation schemes is also assumed to be a factor.

Land use
Afghanistan consists mostly of dry plains and mountains, with only a relatively small part of the land area being suitable for farming and horticulture. There is a tendency to use areas that were originally grasslands as rain-fed wheat crops, even on steep land. This has exacerbated the problems of erosion and destruction of vegetation cover. The rest of the land is rangeland and open steppe or land with little or no vegetation cover. The rivers and the irrigation possibilities they offer are key to productive irrigated agriculture. The productive land can be seen as bands along river valley bottoms and alluvial plains. The construction of water impounding dams and the resulting reservoirs for hydropower generation will in most cases inundate parts of the most valuable and most densely populated rural land in the country.

9.1.3 Hydropower plants (HPPs)

9.1.3.1 120 MW Gulbahar / Panjshir 1 HPP

Gulbahar HPP (also called Panjshir 1) storage project is situated at 35°10'N, 69°17'E on the Panjshir River in the Upper Panjshir Gorge, with the dam site about 3 km upstream of Gulbahar town. The project catchment area is approx. 3,565 km^2 and the mean annual inflow 56 m^3/s. A rockfill dam of 180–200 m height and a crest length of 420 m will create a reservoir about 17 km long and inundate an area of some 13 km^2. If the dam is constructed at 1660 masl at the base, the reservoir water level would attain a maximum of 1840 m. The planned installed capacity is 4×30 MW. The reservoir is planned in the rather narrow Panjshir valley with several larger villages and orchards and intensively used agriculture fields in the valley bottom and hillsides.

9.1.3.2 210 MW Baghdara HPP

The Baghdara reservoir and power plant site is located at 34°49'58.70"N, 69°34'41.53"E on Panjshir River (part of the Kabul River Basin) downstream of Gulbahar. The catchment area is approx. 10,850 km^2 and the mean river flow 99.1 m^3/s, with the highest flow in June for a mean of 351.5 m^3/s and the lowest in January at 29.8 m^3/s. A dam of 90 m height and crest length of 125 m is planned, 4 km downstream of Alekozi. At the planned High Water Reservoir Level (HRWL) of 1460 masl, the reservoir will cover about 33 km^2, and reach up to the confluence of Panjshir River and Ghorband River, which is situated in the Plain of Bagram. The reservoir will serve for seasonal storage and thereby also improve the output of the downstream run-of-river hydropower plants.

9.1.3.3 180 MW Surubi 2 RoR HPP

The Surubi 2 hydroelectric project is located at 34°30'30.74"N, 69°57'0.14"E downstream of the Surubi 1 HPP, so Surubi 2 uses the discharge from Surubi 1. The hydropower plant, with an installed capacity of 180 MW and an average energy production of 890 GWh, is planned at an elevation of 970 masl and will discharge through an 18.9 km tunnel to a tailrace at 770 masl.

9.1.3.4 368 MW Kunar A Storage HPP

The planned HPP site is located at 35°4'34.76"N, 71°21'56.59"E on the Kunar River, about 7 km upstream of Asmar, close to the village of Sangar. The drainage area is approx. 19,960 km^2 and the mean annual flow 370 m^3/s. The Kunar River originates from Pakistan and crosses into Afghanistan at the village Barikov, approximately 39 km upstream of the dam site in Shal/Kunar (Kunar A). The plan is to construct a 160 m high earthfill dam, with a crest length of 1080 m. The crest elevation will be at 1017 masl (HRWL). The reservoir will be about 26 km long. The power plant will utilize a head of 120 m in four units, each 91.5 MW.

The Kunar A HPP dam site is situated at 922 masl. The RoR HPP Project Kunar B (35° 9'56.95"N, 71°25'18.36"E is located at 960 masl, some 14 km upstream of Kunar A. The border of Pakistan is located at 1060 masl. The end point of the reservoir at 1017 masl is 26 km upstream of the dam site of Kunar A and 1.5 km downstream of Nari village, situated at 1030–1050 masl.

9.1.3.5 165 MW Kunar B HPP

The Kunar B hydropower project is located at 35°9'56.95"N, 71°25'18.36"E on the Kunar River about 22 km upstream of Asmar. It has a regulation reservoir with a storage capacity of 7.0 million m^3 and the dam is of the earthfill type, with a height of 105 m. The project site is situated 14 km upstream of Kunar A dam site and 25 km downstream of the Pakistan-Afghanistan border.

The development of the hydropower potential of the Kunar River requires an integrated trans-boundary approach as there are also plans to construct an HPP further upstream on the Pakistan side (see Kunar A).

With regard to capacity, there are some inconsistencies. Whereas the Power Sector Master Plan (Norconsult-Norplan, 2004) indicates that the installed capacity is 165 MW (3 x 55 MW) the National Energy Supply Program (NESP 2012) indicates that the installed capacity is 300 MW. The Main Invest Opportunities in Afghanistan (Afghanistan Investment Support Agency 2009) stated that the hydropower production potential of Kunar river basin is 300 MW (Kunar B – Sagai) in the first stage and 900 MW (Kunar A – Shal) in the second stage. The World Bank Report (Scoping Strategic Options for Kabul River Basin 2010), locates the Kunar B project downstream of Kunar A with a capacity of 81 MW as an RoR HPP.

At the present location and with a planned height of 105 m the Kunar B dam (HRWL 1070 masl) would flood the upper valley of the Kunar River into the territory of Pakistan.

9.1.3.6 45 MW Kama RoR HPP

The Kama hydroelectric plant is located on the Kunar River immediately upstream of its confluence with Kabul River. The project location that was communicated is 34°24'N and 70°34'E which is directly in the flood plain at the confluence of the Kunar and Kabul Rivers. An existing diversion weir is located between two hills at 34°27'32N, 70°33'00E a few kilometers further upstream on the Kunar River. The catchment area is 25,950 km^2 and the mean annual inflow 484 m^3/s. The project is primarily an irrigation project and the power plant will utilize the head on the main irrigation channel. The headrace channel will be 16 km long and the rated head is 85 m.

The confluence of the two rivers is located on a wide, flat river plain with branching river arms and extensive sandy areas. On a slightly higher elevation is a large flat plain with dense habitation and intensive agriculture. The project will provide irrigation water for this area.

According to the Power Sector Master Plan 2004, the project is planned as an additional facility supplementary to an irrigation project. Both the irrigation and power elements will operate on a run-of-river basis.

9.1.3.7 100 MW Kajaki 2 Extension Storage HPP

Whereas all previously considered HPPs are located in the Kabul River Basin, Kajaki HPP is located on the Helmand River, 95 km northwest of Kandahar City at 32°19'22.73"N , 65°6'57.59"E. Most social impacts would arise in the Deh Rahwod district along the Helmand River in Oruzgan Province. The ethnic groups in the district are Paschtu, dominated by the Noorzai and Populzai sub-groups.

Kajaki HPP has a regulation reservoir with a storage capacity of 1.7m m^3. The dam is of the rockfill type and was constructed in 1952 for irrigation purposes. The present dam height is 98 m. The project aims to increase the active storage capacity from 1.7m m^3 to 2.7m m^3. Also proposed is installation of a second power house to generate 100 MW.

The present reservoir level is 1011 masl. According to the Power Sector Master Plan 2004 there were different initial plans for the reservoir (HRWL 1037 masl), but it appears that the reservoir level has never exceeded this mark.

9.1.3.8 Environmental impact implications of hydro power projects

As already noted, the technical data on the extents of water reservoirs and dam heights are first initial figures, so the environmental impacts resulting from these must be considered when the design requirements are better known.

Generally, hydropower projects give rise to the following environmental impacts:

- loss of vulnerable and ecological sensitive areas due to flooding:
  There is a need for further investigations into the presence of rare or endangered species or highly valuable habitats that should potentially be protected.

- change of river water quality because of the reduction of the flow rate and flow velocity, and the changes of fish and fauna species resulting from this

- loss of cultural assets by flooding of river valleys or extent of reservoirs.

The above impacts require further investigation to determine whether there are cultural assets and a detailed survey of fauna and flora.

Considering the above impact potential, the proposed hydropower projects are expected to be categorized as “A” projects likely to have significant adverse environmental impacts that are irreversible. These impacts will affect an area larger than the sites subject to physical works. An environmental impact assessment (EIA), including an environmental management plan (EMP), is required.

9.1.4 Thermal power plants

9.1.4.1 Gas-fired power plants

9.1.4.1.1 Sheberghan Combined Cycle Power Plant (CCPP)

In order to exploit the domestic energy source, a 200 MWe CCPP at Sheberghan is proposed. The plant would be tied into the NWPS grid and will draw from the existing natural gas wells, although development of further wells is needed. The fuel consumption of natural gas is about three times the production rate of the gas field at Sheberghan.

At present, the Consultant does not know which type of power plant is preferred for the Sheberghan power plant but general environmental impacts could be used to evaluate if further consideration of the project would be worthwhile under environmental aspects.

9.1.4.2 Environmental impact implications of CCPP project

Under consideration of the feasibility study for the development of a gas-fired thermal power plant at Sheberghan, prepared by Advanced Engineering Associates International (2006) under the Energy Assistance Program of the U.S. Agency for International Development, the project will have only minor environmental impacts:

Ambient air quality:

- The exhaust gas emission could create an increase of the existing ground level concentrations with respect to the major pollutants, i.e. NO_x, CO, CO_2 and PM. The allowable air emission must be verified by an air dispersion calculation considering the existing background pollution load to be measured over a timeframe of at least 6 months.

- A huge proportion of the gas is distributed as raw, unsweetened, gas. This could result in relatively high SO_2 emission levels. Specific attention must be directed to the need for sulfur removal but this will result in the need for sulfur disposal unless a productive utilization of the produced sulfur can be identified.

Water resources and water quality

- Air cooling is suggested but a certain amount of water will still be consumed. A reliable water source must be identified to reduce potential drop of the ground water level and the overuse of surface water bodies.

- Procedures and technical solutions must be established to properly store, handle, transport and treat all type of liquids and effluents at site to avoid any resulting environmental impacts on the ground and on water bodies.

Noise concerns

- Noise mitigation measures must be implemented if predictions indicate that environmental and occupational noise levels will be exceeded.

Solid and hazardous waste

- Solid waste generated as a residue from operations as well as hazardous materials must be properly stored at site until suitable waste management possibilities including appropriate final disposal become available. Special attention must be paid to the need for bottom sealed areas to prevent intrusions of spills and leaks into the ground.

Landscape

- The scenery of the proposed power plant will be widely visible. Mitigation measures to avoid such an impact are not possible to implement. Therefore suitable compensation impacts must be selected.

Should the CCPP at Sheberghan be selected for further development, the following environmental investigations should be considered to confirm the above initial environmental assessment and to ensure that a reliable environmental baseline is established for a detailed environmental impact evaluation for both the construction and the operation phases:

- Baseline ambient air quality measurements for NO_x, CO, CO_2 and PM should be undertaken for a period of at least 12 months to ensure that the full seasonal variation is monitored.

- An air dispersion model should be calculated to predict and estimate the contribution of plant operation over and above the existing baseline conditions, and emission reduction measures must be considered if it is expected that limit values will be exceeded. The appropriate stack height must be determined to ensure proper dispersion of air pollutants.

- If ground water or surface water resources are to be used, an expert study should be prepared to estimate the impacts of raw water use as well as of discharge of treated process, cooling or sanitary waste water to the receiving waters.

- A survey of fauna and flora should be undertaken to ensure that no rare or endangered species will be affected by the project.

- As far as necessary, mitigation and compensation measures should be developed to reduce potential environmental impacts to as low a level as reasonably practicable.

- Environmental monitoring measures should be implemented to detect changes in ambient air quality and noise levels as well as the success of any mitigation and compensation measures that may be needed.

This scheme is classified as Category A because it is likely that it will have significant adverse environmental impacts affecting an area larger than the proposed project site subject to physical works. An environmental impact assessment (EIA), including an environmental management plan (EMP), is required.

9.1.4.3 Coal-fired power plants (CFPP)

9.1.4.3.1 Ishpushta and Dara e Suf Coal-Fired Power Plants

A 400 MW coal-fired thermal power plant is planned at Ishpushta in Bamyan Province for power supply to the copper mine at Aynak. The exact location of the coal mine is not known to the Consultant. A power supply agreement was signed a few years ago envisaging a 50/50 power share between the mine and the national grid. Accordingly, 200 MW shall be fed into the Afghan grid. A second coal-fired thermal power plant with a capacity of 800 MW is planned at Dara e Suf in Samangan Province to supply the iron ore mine at Hajigak. The exact location of the coal mine is not known but it is noted that both these projects will be located in a relatively unproductive area.

Realization of these two power plant projects is not expected before 2027.

The timeframe between now (2012) and the expected realization of the projects (2027) is significantly long. It will take at least 15 years up to a possible start of construction and in addition it is still unknown if the discovered coal fields could be commercially exploited.

Because at present no preliminary design information is available nor any details of the coal quality, the environmental evaluation is based on the existing and available data and will provide a first initial overview together with recommendations to be considered for the upcoming project phases.

9.1.4.4 Environmental impact implications of CFPP projects

The following impacts are expected to be substantial and should be taken into account for the further decision process:

Ambient air quality

- Flue gas emissions could increase ground level concentrations beyond the baseline with respect to the major pollutants, NO_x, SO_2, CO, CO_2 and PM. PM concentration also could increase from dispersion of coal ash from ash and coal yards. Allowable air emissions must be verified by an air dispersion calculation considering the existing background pollution load to be measured over a timeframe of at least 6 months.

Water resources and water quality

- Air cooling is suggested but a certain amount of water will still be consumed. A reliable water source must be identified to reduce the potential for lowering the ground water level and overuse of surface water bodies.

- Procedures and technical solutions must be established to properly store, handle, transport and treat all types of liquids and effluents on site to avoid any environmental impacts on groundwater and surface water.

Noise concerns

- Noise mitigation measures must be implemented if environmental and occupational noise forecasts predict that tolerable levels will be exceeded.

Solid and hazardous wastes

- Solid waste generated as an operating residue as well as hazardous materials must be properly stored on site until suitable waste management possibilities together with appropriate final disposal become available. Specific attention must be directed to the need for basal sealing to prevent intrusion of spills and leaks into the ground.

Landscape

- The proposed power plant will be widely visible within its scenic setting. Mitigation measures to preclude such an impact cannot be implemented, so appropriate compensatory measures must be identified.

Should one or both of the recommended projects be chosen for further development, an environmental investigation as follows should be considered to confirm the above initial environmental predictions and to ensure that a reliable environmental baseline is established for a detailed environmental impact evaluation for both construction and operation phases:

- Baseline ambient air quality measurements for NO_x, SO_2, CO, CO_2 and PM should be undertaken for at least 12 months to ensure that the full seasonal variation is monitored.

- An air dispersion model should be calculated to predict and estimate the contribution of plant operation over and above the existing baseline conditions.

- If ground water or surface water resources have to be used, an expert study should be undertaken to estimate the impacts of raw water use and discharges of treated process, cooling and sanitary waste water on the water resources.

- A fauna and flora survey should be undertaken to ensure that no rare or endangered species will be affected by the project.

- Suitable mitigation and compensatory (if needed) measures should be developed to reduce possible environmental impacts to as low a level as reasonably practicable.

- Environmental monitoring measures should be implemented to detect changes in ambient air quality and noise levels as well as assess the success of potentially needed mitigation and compensatory measures.

These projects are classified as Category A because it is likely they will have significant adverse environmental impacts affecting an area larger than the proposed project sites subject to physical works. An environmental impact assessment (EIA), including an environmental management plan (EMP), is required for the subsequent project phase.

9.1.5 Transmission line projects

9.1.5.1 TKM border via Shebergan to Pul-e-Chomri

This 500 kV transmission line runs from the TKM border via Andkhoy and Shebergan to Pul-e-Chomri. The line routing from TKM via Andkhoy to Shebergan (108 km) has been assessed in an IEE (Fichtner, 2012). The line routing from Shebergan to Pul-e-Chomri has not yet been determined. It is currently expected to cross semi-arid and desert lowlands.

9.1.5.2 500 kV transmission line from Pul-e-Chomri to Chimtala

The 500 kV transmission line from Pul-e-Chomri to south of Kabul via the "Bamyan Route" (alternative to Salang Pass) will pass by the area of the Afghan coal deposits in Samangan and Bamyan and will further cross the area of the Hajigak iron deposit. The total length of this line is approx. 316 km. The line route traverses around 50 km of cultivated lands in the often narrow valleys.

9.1.5.3 220 kV transmission line from Dasht e Barchi to Kandahar

The proposed NEPS-SEPS Connector is an approx. 481 km single-circuit (S/CKT) 220 kV transmission line from the proposed Dasht-e-Barchi Substation to the proposed Kandahar East Substation.

9.1.5.4 Pul-e-Chomri 500 kV/220 kV Converter Station

This new converter station is planned to be built near the site of the existing substation. Two new 500 kV transmission lines will terminate there. It is planned to be built on semi-arid barren land, with no settlements and agriculture use.

9.1.5.5 Dasht e Barchi 220/110/20 kV Substation

Dasht-e-Barchi Substation will be located to the south of Kabul, about 15.9 km from Chimtala Substation, near the A1 road on barren land.

9.1.5.6 Environmental impact implications of transmission infrastructure projects

The following impacts are expected to be substantial and should be taken into account for the further decision process:

<u>Landscape</u>

- Towers and transmission lines will be widely visible within the landscape. Mitigation measures to preclude such an impact cannot be implemented, so appropriate compensatory measures must be identified.

Liquid hazardous waste

- Generated liquid hazardous waste as a residue from operation of the converter station and substations must be properly stored on site until suitable waste management possibilities together with appropriate final disposal become available. Specific attention must be directed to the need for basal sealing to prevent intrusion of spills and leaks into the ground.

Wildlife

- It is anticipated that the towers and transmission lines will be an obstacle for birds and bats, resulting in a loss of an unpredictable number of individuals.

Should the above described projects be chosen for further development, an environmental investigation as follows should be considered to confirm the above initial environmental predictions and to ensure that a reliable environmental baseline is established for a detailed environmental impact evaluation for both construction and operation phases:

- A bird and bat survey considering mitigation times and routes should be undertaken to ensure that the number of possible collisions could be reduced.

These projects are classified as Category B with the potential for site-specific adverse environmental impacts. An initial environmental examination (IEE), including an EMP, is required.

9.1.6 Conclusion

All evaluated projects are classed as Category A under the ADB environmental rules because it is likely that they will have significant adverse environmental impacts that are irreversible, diverse, or unprecedented. These impacts will affect an area larger than the proposed project sites subject to physical works.

Independently of the fact that significant technical information is still outstanding and therefore not available at a Master Plan level, it could be concluded that currently no concerns were identified with the potential to exclude one or more of the proposed projects from further consideration in the project development process. If one or more of the suggested and recommended projects proceed further, it is to be emphasized that at least on feasibility level, a detailed environmental impact assessment is required, considering technical design data and details to allow comprehensive and intensive discussion of all potential environmental concerns that may arise during construction and operation.

In addition, the Consultant recommends undertaking the suggested detailed field investigations to establish a reliable, appropriate and suitable environmental baseline to allow a precise impact assessment based on design solutions appropriate to reduce the environmental impact to as low a level as reasonably practicable. In the absence of environmental baseline information and the required technical information, none of the proposed projects should be recommended for further consideration.

9.2 Review of Social Safeguard Implications

9.2.1 Introduction

The basic rationale for including social aspects in the planning of power projects is to increase the chances of selecting projects that are socially sustainable. At an early stage in planning high negative social impacts can still be avoided or mitigated by design.

Social impacts of energy infrastructure projects are mainly related to land use, land acquisition and resettlement issues which are the subject of Land Acquisition and Resettlement Plans (LARP) as well as other Environmental, Health and Safety (EHS) impacts that arise during construction and operation and which are the subject of Environmental Impact Assessments and Environmental Management Plans (EIA/EMP).

The investigations into the social safeguard implications of the projects selected through the optimization process have been carried out as desktop studies based on available documents and information. Because detailed, recent and reliable social data from the project micro-regions are lacking, data is extrapolated from similar regions in the country or the available national data. Further interpretation is made on the basis of satellite images. Public consultations could not be carried out due to the difficult security situation in the country but will have to be conducted intensively at later project stages.

The selected projects will generate positive and negative social impacts on various levels, with differing magnitudes and sensitivity. Major impacts – apart from the positive impacts, i.e. benefits from electricity supply, income generation etc. – will arise from permanent land acquisition and resettlement as well as temporary disturbances. For permanent impacts, mitigation measures include land-for-land as well as cash compensation and involuntary resettlement with full restoration of lost assets, depending on the magnitude of the impact. For temporary impacts, appropriate compensation mechanisms will have to be devised.

A strong component of Local Area Development Planning (LADP) to ease social and environmental impacts and alleviate the poverty of the resident population (beyond the physically affected persons) may further contribute to a better acceptance of created infrastructure and increase the social benefits for each sub-project area.

A detailed estimate of land acquisition and resettlement impacts and entitlements would require in-depth field studies for each of the selected projects that exceed the remit of this Master Plan. However, especially for the large and medium sized hydropower projects, detailed studies of the resettlement requirements will be necessary.

Nevertheless, an attempt is made to screen the projects that have been selected through an economic optimization process regarding their social safeguard implications within national and international safeguard frameworks.

9.2.2 Legal frameworks

9.2.2.1 National legal framework

The National Legal Framework establishes the legal basis for implementation of project-related land acquisition and resettlement (LAR) processes that allows a comparison with international regulations and Bank safeguards. This includes procedures for land expropriation in the public interest, compensation and involuntary resettlement frameworks.

In Afghanistan, the LAR legislation is based on the new Constitution of Afghanistan which was ratified in early 2004. There are a few articles on the subject of land in the broader sense, but mainly two Afghan laws are relevant for land acquisition and resettlement:

- the “Law on Land Management” (LML), and the
- “Land Acquisition Law” (LAL).

A comprehensive land policy was first approved in 2008 by the President, published on 31 July 2008. This “Law on Land Management” (no. 985) aims at creating a legislated unified and reliable land management system. One major challenge of the law was to provide a solution to the previous untenable situation caused by the existing heterogeneous and contradictory land management and land title systems and regulations in Afghanistan.

9.2.2.2 International safeguards

In addition to the National Legal Framework, international safeguards will have to be respected. In the following, ADB Guidelines as well as World Bank Operational Policies (OP) are considered.

The ADB requires social and environmental assessments of all project loans, program loans, sector loans, sector development program loans, financial intermediation loans, and private sector investment operations.

The following ADB guidelines apply:

- Safeguard Policy Statement (SPS), June 2009, effective since January 2010
- Land Acquisition and Resettlement Framework (LARF), updated by Fichtner in September 2012
- Operations Manual (OM) with relevant Bank Policies (BP), March 2010.

The objective of the ADB safeguard policy for involuntary resettlement is to “avoid resettlement wherever possible; to minimize involuntary resettlement by exploring project and design alternatives; to enhance, or at least restore, the livelihoods of all displaced persons in real terms relative to pre-project levels; and to improve the standards of living of the displaced poor and other vulnerable groups” (SPS 2009).

The involuntary resettlement impacts of an ADB-supported project are considered significant if 200 or more persons will be physically displaced from their homes or lose 10% or more of their productive or income-generating assets.
The objective of the indigenous peoples safeguard requirements is to “design and implement projects in a way that fosters full respect for Indigenous Peoples’ identity, dignity, human rights, livelihood systems, and cultural uniqueness as defined by the Indigenous Peoples themselves so that they: (i) receive culturally appropriate social and economic benefits, (ii) do not suffer adverse impacts as a result of projects, and (iii) can participate actively in projects that affect them” (SPS 2009). Indigenous Peoples Development Plans (IPDPs) will have to be established where indigenous people are affected.

As in the context of Afghanistan a high percentage of affected persons (APs) will be considered to be vulnerable APs, special assistance will be required. Local Area Development Plans (LADPs) should be set up for all projects considered under this Master Plan.

In World Bank operations, the Social and Environmental Assessment (SEA) plays a key role in ensuring that project options under consideration are sound and sustainable from an environmental and social point of view.

The relevant environmental and social policies are:

- Environmental Assessment (OP 4.01)
- Natural Habitats (OP/BP 4.04)
- Water Resources Management (OP 4.07)
- Indigenous People (OP 4.10)
- Cultural Property (OP 4.11)
- Involuntary Resettlement (OP 4.12)
- Safety of Dams (OP/BP 4.37)
- International Waterways (OP 7.50).

OP 4.10 and **OP 4.12** are considered especially relevant from a **social perspective**. The other policies may have links to social aspects, but concern mainly environmental issues, therefore they are considered in the Environmental Safeguards / EIA framework.

In the Final RPT for Land Acquisition in Afghanistan, the World Bank notes, that "the first step addressed by OP 4.12 is avoidance of land acquisition and resettlement if possible. Land acquisition and resettlement should not be seen as the easy first option; rather it should be seen a last resort." (World Bank, 2007). This should be taken into account even if paying market price compensation is less costly than avoiding resettlement if this is feasible.

9.2.2.3 Gap analysis

Although reforms in legislation have been implemented during the last few years, there are still many contradictions between formal and common (traditional) law, gaps mainly with regard to land transfer processes, and there are neither binding procedures for valuation and compensation nor an index for the valuation of losses in case of expropriation.

There are also shortcomings in enforcement of the regulations. There is still a considerable lack of institutional capacities for implementation, monitoring and evaluation. There is a lack of specific Social and Environmental (S&E) qualification of staff and a specific S&E department does not exist within the implementing institution (DABS), in part the existing structures are overloaded with work and staff is not sufficiently remunerated. To some extent, the number of highly qualified staff is not sufficient to cope with the amount of work to guarantee an effective enforcement of the regulations.

The lack of access to legal support and lack of trust in the institutions, especially for weaker sections of the society, may create further gaps for implementation of compensation and resettlement. Additional training would be a necessary component to improve implementation and monitoring performance. Compliance with international safeguards could be facilitated with independent monitoring by internationally experienced auditors and consultants.

In the case of differences between both frameworks, the stricter regulations will have to be applied in favor of the project Affected People (AP). If the national framework is stricter than international safeguards, then the national framework will have to be applied. If the international safeguards are stricter than the national framework, the international safeguards will have to be applied, so guaranteeing compliance with both legal frameworks.

9.2.3 Socio-economic characteristics

9.2.3.1 Population

Afghanistan faces enormous recovery needs after three decades of war, civil unrest and recurring natural disasters. Despite recent progress, millions of Afghans still live in severe poverty with a crumbling infrastructure and a landscape that is suffering from environmental degradation. The rugged, landlocked country remains one of the poorest in the world, with more than half the population living below the poverty line (WFP, 2012). The United Nations Development Program (UNDP) ranks Afghanistan 172nd out of 186 nations in the Human Development Index, and the CIA estimates its per capita income as ranking 214th in the world out of 226 countries (UNDP, 2011). The 2007–2008 National Risk and Vulnerability Assessment (NRVA) found that **7.4 million people** – nearly a third of the population – are unable to get enough food to live active, healthy lives. Another **8.5 million people**, or 37%, are on the borderline of food insecurity. Around **400,000 people each year** are seriously affected by natural disasters, such as droughts, floods, earthquakes or extreme weather conditions (CSIS, 2012). The entire population of Afghanistan is estimated at around 30 million, up from 15.5 million in the 1970s. The population growth of Kabul is even faster than in other regions, so the population of Kabul province (see table below) is expected to double in coming years. (WFP 2012)

9.2.3.2 Socio-economic situation

Total GDP amounted to approximately 15 billion US$ in 2010. Per capita income stands at around 591 US$ in 2011/2012. The past decade has been characterized by annually fluctuating GDP growth rates. Starting at 8.4% in 2003/04, the growth rate dropped to 1.6% in 2004/05 just to soar back to 11.2% in 2005/06. Likewise the following five years have been marked by ups and downs, reaching an unsustainable peak at 21% in 2009/10 and falling back to 8.4% in 2010/11. The high levels of volatility are due to the predominance of the agricultural sector that is subject to weather fluctuations. (WFP 2012)

Only 10–24% (according to different estimates) of the population have intermittent access to publicly provided power, and per capita electricity consumption is as low as 21 kWh per year. Many load centers around the country get electricity only for 2–3 hours a day. Such electricity shortage affects people in urban and rural areas alike, and constrains economic growth. (Fichtner 2012).

9.2.3.3 Health

While life expectancy has increased slightly to 44.5 years for men and 44 for women, many of the country’s health indicators are alarming. Along with a high infant mortality rate, Afghanistan suffers from one of the highest levels of maternal mortality in the world of 1600 deaths per 100,000 live births. More than half of children under the age of five are malnourished, and micronutrient deficiencies (particularly iodine and iron) are widespread (WFP 2012). Increased electricity supply at hospitals would contribute to improved health care. The selected Power Sector Development projects could contribute to a stabilization of electricity supply in the urban centers and to some extent focus on the improvement of Health Centers in the framework of rural electrification programs and Local Area Development Plans (LADP).

9.2.3.4 Education

The formal education sector is slowly improving, but progress is hampered by a shortage of qualified teachers, poor facilities and threats posed by insurgents. Even so, over two-thirds of school-age children attend school. Girls, banned from school under the Taliban regime, are gradually returning to the classroom, but 70% are still not enrolled. Adult literacy rates remain low, at 43% for men and 14% for women (WFP 2012). Access to electricity is often missing at schools, so reducing possibilities for lighting and heating. This could be a focus of the framework of rural electrification programs and Local Area Development Plans (LADP).

9.2.3.5 Gender

The Afghan government has removed severe discriminatory laws against women; ratified a constitution that promotes non-discrimination; and facilitated women’s participation in national elections through civic education, voting and candidacy. There have been some notable improvements in the participation of women in public life, including in the Interim

Administration, Emergency Loya Jirga, and national and local elections. Achievements are also being made at the local level, largely because of the growing focus within the government and among donors on providing aid assistance directly to communities. Women, who have traditionally not been consulted on community issues, are now being included in forums to determine village and neighborhood development priorities, and to design and implement projects to address their problems. (The Asia Foundation, 2009)

Despite these achievements, ten years after Taliban rule, Afghanistan’s rights situation remains extremely poor. Armed groups routinely engage in extortion and violence against communities, while the Taliban continues to conduct attacks that indiscriminately or intentionally harm civilians. The situation for women’s rights is particularly bad, with threats and attacks by insurgents on women leaders, schoolgirls, and girls’ schools, and police arrests of women for “moral crimes” such as running away from forced marriage or domestic violence. (HRW, 2012)

However, due to the fact that the stabilization of the central electrical power networks supports women and men in a more or less equal manner, the projects considered within the Power Sector Master Plan do not favor strategic gender needs and do not support changing the gender relations between women and men. As a consequence, it is assumed that the project according to the OECD/DAC gender categories has to be classified as gender-neutral.

9.2.3.6 Ethnic groups and indigenous peoples

Afghanistan has more than 40 ethnic groups, the largest of which is the Pashtun (53%), generally residing in the eastern and southern regions. The Tajiks in the northeast (17 %) and Turkic groups in the northern plains (20%) are the second- and third-largest groups. However in most areas, groups are mixed. The Hazara and the Kuchi (nomads) are considered among the most vulnerable groups as there has been a history of discrimination against members of these ethnic groups. (Fichtner 2012)

The Kuchi may be considered as indigenous peoples regarding their social situation, traditional lifestyle and dependence on natural resources. However, this aspect has to be studied in depth for the projects with major land acquisition and resettlement impacts, mainly for HPPs.

As the situation between different ethnic groups is tense in some regions and the struggle for livelihood resources is hard, unequal distribution of project benefits could fuel inter-ethnic conflicts. A conflict analysis for each infrastructure project is recommended during feasibility studies and the final design stage. Public consultations should be held separately with members of all ethnic groups so as not to disadvantage one particular ethnic group and fuel potentially existing conflicts.

9.2.3.7 Land use

Currently, 5% of farms in Afghanistan are located on 40% of the arable land. 73% of farms are less than five hectares, with the average farm size being 1.6 hectares. Nationally, 21% of rural households are landless. The poorest households are those headed by women and the landless. Almost 5 million refugees have returned to Afghanistan from Pakistan and Iran since 2002; a majority of these are landless or have returned to find that their land had been taken in their absence. They are often forced to join the growing population that inhabits squatter settlements in urban areas. Of the 2 million refugees still in Pakistan, 90% reportedly have no access to land or housing in Afghanistan.

Land ownership can be acquired through purchase, government land allocation, and transfer of ownership, such as through inheritance. Most people acquire rural land through inheritance transfers, which often precede death. Nomadic or semi-nomadic people may acquire pasture land for grazing their livestock through application to the local authorities stating the need for land, and through the identification of vacant land (mawat). Individuals can apply for ownership rights to mawat land by showing that no-one has ownership rights to it and that the land is not cultivated or improved, and by agreeing to cultivate or improve the land.

Afghanistan does not have an adverse possession law. Holders of land rights under customary law cannot obtain ownership simply through the passage of time and exclusive possession of land. The formal law also does not provide a means to formalize informal rights to land or regularize de facto ownership. USAID's LTERA project tested community-based models for formalizing the rights of informal settlements, and legislation governing the formalization of informal rights is anticipated (Gebremedhin 2006; Gebremedhin 2007; EMG 2010).

In general, land rights tend to be highly insecure. In rural areas, the key drivers of insecurity are: (1) a history of inequitable relations within communities with regard to access and rights to land and water; (2) multiple unresolved interests over the same land, including rights of nomads; (3) failure to develop accepted principles governing holdings of non-agricultural land; and (4) continuing violence and disorder, uncontrolled poppy production, warlords, land invasions, and ethnic disputes. In urban areas, the vast majority of landholdings are informal, often contrary to formal law, and insecure (World Bank 2005). The exodus of Afghans to other countries during decades of conflict has been a significant cause of tenure insecurity. Afghans returning to Afghanistan find their land and houses inhabited by other families and communities. In other cases, changes in government may result in loss of rights.

Almost all land is registered in the name of the male head of household. In urban settings, female heads of household and widows are increasingly asserting their rights to land, but they are unlikely to try to register their rights formally because the process is time consuming and costly (Grace 2005; Beall and Esser 2005).

The registration process is lengthy and expensive; it requires completion of a number of forms, securing no objections from up to five offices, payment of tax at 5–7 % of the value of the land etc. While the primitiveness of document management is a bureaucratic issue, the integrity of the system is a greater concern, long considered corruptible, and the records are widely corrupted; including widespread production of counterfeit documents. Real adjudication is rarely carried out, relying on selected witnesses, often self-selected. At the community level, owners with medium-sized lands tend to hold locally witnessed evidence of transfers, including distribution at inheritance variously referred to as customary or Shari's land deeds. Such records are rarely held by the majority of land-poor smallholders. Finally, there are a large number of land grant deeds. Although land ownership documentation and registration exists, its reliability and utility is questionable due to documentation and registration problems in the past. (Fichtner 2012)

Land conflicts exist in a myriad of forms and result from diverse circumstances. For example, conflicts can take the form of non-violent inheritance disputes among siblings; ethnicity-based provincial-level conflicts that result in casualties and significant damage to property and livestock; and group-based land-appropriation that perpetuates inter-community tensions.

9.2.3.8 Conflict setting

In Afghanistan in general, insecurity is a major and growing concern. Insurgent activity and military operations have undermined reconstruction efforts, restricted humanitarian interventions and negatively affected food security in some regions (WFP, 2012). The conflict situation has also affected private entrepreneurship, local initiatives and infrastructure maintenance and extension. Under these circumstances, prospects for the post-2014 transition period are uncertain.

9.2.3.9 Landmines

Afghanistan is one of the most heavily mined countries in the world. In spite of years of intensive mine clearance, hundreds of square kilometers remain to be cleared. Most project sites are situated in areas where the presence of landmines cannot be excluded. Special Assessment and Clearance is required by UNMACA before initiation of any project activity.

9.2.4 General impacts related to power production and transmission

9.2.4.1 Positive social impacts of improved electricity supply

Energy is an important factor for development. It contributes to fulfilling the most basic and essential needs for human survival. Private use of electricity includes lighting, cooking, heating, use of electrical household devices (e.g. of sewing machines), in rural areas also small-scale agro processing (e.g. honey centrifuges, dairy accessories), etc. In general, the household workload (mainly of women) is alleviated and time is saved if electricity can be supplied. Especially in urban centers and for industrial development and extraction of natural resources/mining a more stable electricity supply is required. While many stakeholders see the impact of an improved energy supply especially in terms of economic growth and additional employment, the resulting improvement in living conditions among large sections of the population as a result of such a development should also be viewed as a notable contribution to poverty alleviation. However, as a precondition for poverty alleviation, the electricity needs to reach the poorer sections of the society and the more remote areas. From a socio-economic perspective, decentralized electricity generation and rural electrification should therefore be integral parts of energy development planning to maximize the positive socio-economic impacts.

The electricity needs of Afghanistan and especially for the growing population of Kabul as well as the industrial needs to exploit the mining resources of the country, e.g. Aynak copper and Hajigak iron, are detailed in Chapter 3 of this Power Sector Master Plan Document.

9.2.4.2 Transmission lines (TL) and substations (SS)

Construction of transmission lines generally gives rise to the need for permanent land acquisition at tower foundations and substation sites. Short-term impacts are damage to agricultural land and crops that arise during land surveying and stringing of conductors. Other, temporary social impacts, like health and safety, are the subject of EIA/EMP mitigation measures.

The most critical impact of transmission line construction concerns displacement of affected people from the entire line corridor. For safety reasons (EMF) all settlements have to be removed from the line corridor (RoW) and relocated in a suitable place where the livelihoods of all affected persons (APs) have to be fully restored.

The Right of Way (RoW) corridor should be 60 m for a single-circuit 500 kV line and 40 m for a single-circuit 220 kV line. Complete clearing is required in the center strip of 25 m and 15 m in dense forest, to permit conductor stringing.

Outside this narrow stringing corridor but still within the RoW, all vegetation higher than 3 m has to be cleared, including tall, potentially dangerous trees near the corridor. In the mostly semi-arid or desert landscape of Afghanistan, RoW clearing can be limited to a minimum.

As a precautionary measure, other projects have adopted an internationally accepted standard RoW width of 60 m along their HV transmission lines of 500 kV, compared with 40 m for 220 kV lines. All habitation and structures are excluded from the RoW to ensure safety of people and animals from EMFs as well as from direct electric shocks and “flashover”. No permanent human presence is to be allowed within the RoW.

In the frequency range up to 1 kHz, the general public reference levels for electric fields are one-half of the values set for occupational exposure. The value of 10 kV m-1 for 50-Hz or 8.3 kV m-1 for a 60-Hz occupational exposure includes a sufficient safety margin to prevent stimulation effects from contact current under all possible conditions. Half of this value was chosen for the general public reference levels, i.e. 5 kV m-1 for 50 Hz or 4.2 kV m-1 for 60 Hz, to prevent adverse indirect effects for more than 90% of exposed individuals.

From similar projects it can be stated that the relevant internationally accepted limit values for the public will not be exceeded if the minimum safety distance of 8 m to the nearest conductor is kept as recommended. However, routine EMF measurements are recommended.

In the context of Afghanistan, electricity transmission line projects are generally located in two types of landscapes. One type is a flat semi-arid to desert steppe with only seasonal rivers that is very sparsely populated and only partly usable for agriculture (Type 1). Villages, mostly in the form of grouped settlements, are rather easily avoidable, due to the available space and sparse population in this type of landscape. The other type of landscape is mountainous regions, with steep and sometimes forested slopes and fertile river valleys, in which the population is concentrated in small grouped villages or scattered farms along the course of the rivers (Type 2). Impacts are expected to be more important in Type 2 landscapes (mountainous regions), especially for construction of access roads, acquisition of agricultural land and resettlement issues.

Common to both types of landscape in Afghanistan is that presently they form the background for a long-term conflict setting. Security issues are prevalent, with the need for landmine assessment and possibly de-mining as well as social conflicts to be taken into account.

Transmission lines are neither expected to have an impact on gender equality nor impacts on indigenous peoples` livelihoods. However, it is important to note that existing land use practices, like grazing and agriculture, can be pursued in RoWs.

Substations require approximately 2 ha and will normally give rise to very little resettlement needs if the site is carefully chosen.

9.2.4.3 Thermal power plants (TPP)

Thermal power plants fire fossil fuels to generate electricity and so give rise to emissions that may create social impacts on the health of resident populations and, in the long run, cause climate change. However, natural gas-fired power plants combining the combustion turbine Brayton cycle with a tailing steam turbine Rankine cycle, referred to as combined cycle power plants, are the fossil fuel power plant type with the highest energy efficiency of up to 50%. Natural gas is considered to be the cleanest fossil fuel as the combustion by-products are mostly carbon dioxide (CO_2) and water vapor with very small amounts of nitrogen oxides, NO_2 and NO_x, and hardly any other substances. To produce the same quantity of electricity through combustion, natural gas will generate approximately 30% and 45% less CO_2 than oil and coal respectively.

Nevertheless, a 200 MW CCNG power plant will still produce approximately 350 Gg CO_2 annually. A 400 MW (800 MW) coal-fired power plant with best available technology (BAT) will thus produce approximately 1,300 (2,600) Gg CO_2 annually. Other emissions of coal-fired power plants (CFPP) are treated within the environmental impacts and safeguards section. (Fichtner 2012)

In addition to air emissions, water emissions, especially rejection of heated cooling water, are a concern for the ecology of the water resources and so for the people who are dependent on this resource. In areas with water scarcity, like Northern Afghanistan, power plants with air-cooled condensers greatly reduce water use.

Resettlement and land acquisition impacts for the construction site and ancillary infrastructure are considered to be low, as – in the context of Afghanistan –power plants are located in uninhabited areas and space requirements are comparatively low when compared to hydro storage power plants for instance. Ancillary infrastructure like pipelines and access roads will require land but normally give rise to little need for resettlement.

Most social impacts can be mitigated by design and use of the best available technology (BAT) and implementation of an environmental management plan (EMP), except the impact on climate change, that would require large scale clean development mechanism (CDM) or carbon sink development projects.

9.2.4.4 Hydro power plants (HPP)

In addition to the benefits of electricity generation, hydro power plants with reservoirs can have other positive socio-economic impacts, such as increased potential for irrigation, creation of fishing opportunities for local residents and protection from floods through absorption of peak flows. Also, the generation of construction work opportunities for local labor is significant. In particular, the possibility to meet peak energy demand during low flow periods in winter is highlighted as a benefit of storage HPP.

On the other hand, negative social impacts generally increase in severity with the size of the hydropower plant and its storage capacity. Whereas run-of-river (RoR) hydropower plants mostly do not give rise to severe negative social impacts, construction of HPPs with reservoir dams usually require significant land acquisition in the reservoir areas, along with resettlement and rehabilitation of the population and their economic assets displaced due to the project (World Bank 2010).

According to the World Bank Report ‘Scoping Strategic Options for Kabul River Basin’ (2010), ”it is clear that a number of dams being considered in this study will involve significant displacement of people”. This is especially relevant for three of the selected Power Sector Master Plan projects: Gulbahar/Panjshir 1 HPP, Baghdara HPP and Kunar A HPP.

According to the World Bank (2010) it is necessary that “while determining the cost of storage options, account must be taken of the cost of resettlement and economic rehabilitation of the displaced population including their lost assets, livelihoods, and public infrastructure. These costs will differ between HPP reservoir options because of local conditions, but in most cases they will account for a major part of the cost of water reservoir development”.

This is particularly important in Afghanistan, where the rural population and agricultural activities are usually located along river valleys close to the river, and where the remaining land is largely unfertile desert land. Additionally people have already suffered a long period of social disruption and displacement and social conflicts (about land issues) are ongoing.

The most severe social impacts are inundation of agriculture and forest lands and displacement of local populations, but also potential deterioration of water quality and dams acting as barriers for fish migration may give rise to negative socio-economic impacts. Impacts of ancillary infrastructures, like electricity transmission lines and access roads etc., need to be taken into account under the EIA and LARP procedures.

Especially in the cross-border context of Afghanistan and Pakistan, like in the Kabul River Basin, including the Panjshir and Kunar rivers, downstream impacts and the implications of the international waterways directive need to be considered.

9.2.5 Social screening of Master Plan elements

9.2.5.1 Update of the Power Sector Master Plan (2004)

The previous Power Sector Master Plan was prepared in 2004 by Norconsult-Norplan, in 2004 with the support of the World Bank. Due to various factors, among which are the population increase between 2004 and 2007 and the significant underestimation of Kabul’s electricity needs in 2007, an update of the Master Plan 2004 was decided.

Meanwhile, feasibility studies including environmental and socio-economic studies have been undertaken for some projects, especially transmission lines. For other projects, especially hydropower plants, (pre-)feasibility studies have only partly been undertaken, or if so, reports have not been made available to the Consultant. Screening of the social impacts will take into account the latest available information.

The Power Sector Development Master Plan (2012) focuses mainly on the development of the national energy supply for Afghanistan via centralized energy production and transmission infrastructure which aims at the same time at improving independence from energy imports from neighboring countries, which is a choice made by the Government of Afghanistan.

The projects are selected according to these priorities and the selection is narrowed down by an economic optimization process, to be subsequently screened from a socio-economic perspective.

The Master Plan includes several project categories: a) Transmission lines and Substations, b) Thermal Power Plants (Gas and Coal) and c) Hydropower Plants, as well as a few considerations of d) Renewable Energies.

9.2.5.2 Transmission lines and substations

9.2.5.2.1 TKM border to Shebergan and Pul-e-Chomri

The 500 kV transmission line runs from the TKM border via Andkhoy and Shebergan to Pul-e-Chomri. The line routing from TKM via Andkhoy to Shebergan (108 km) has been assessed in an IEE and LARF (Fichtner, 2012). The line routing from Shebergan to Pul-e-Chomri has not been determined yet. In total, due to the line routing in uninhabited semi-arid and desert lowlands, potential social impacts are limited to the few areas where towns and agriculture regions are traversed.

With careful line routing and best practice of access road construction as well as careful stringing procedures, LAR impacts will be minimal for the line section TKM border to

Shebergan. The line routing from Shebergan to Pul-e-Chomri is not yet known but a similar situation is expected. Settlement areas will be detoured to minimize resettlement needs.

From the field survey, only one very problematical area has been identified with up to eight houses and courtyards in Andkhoy which might require a shift of the line route or alternatively will have to be resettled. It is expected that not more than 15 to 30 owners could be affected, assuming that no new constructions will be approved between August 2012 and the start of civil works. Again, the final number can only be determined during the final technical design of the transmission line. (see LARP MFF T4, Fichtner 2012)

According to an estimate used for preparation of the LARF, in total 134 farmers with irrigated land and 120 farmers with non-irrigated land could be affected. However, these figures are based on information provided during the survey in August 2012. At the stage of the Detailed Census Survey and Inventory of Losses, the number of affected farmers might increase or decrease. Agriculture will remain possible in the RoW.

OP 4.12 and ADB SPS (2009) involuntary resettlement safeguards are triggered by the project.

The area of the RoW and all other work and access areas will have to be confirmed as being free from landmines and other unexploded ordnance (by UNMACA).

If the line between Shebergan and Pul-e-Chomri is specified to minimize impacts on settlements, the project will most likely be assessed as Category B. A detailed LARP including AP census and Inventory of Losses will have to be made after detailed line design.

9.2.5.2.2 Pul-e-Chomri - Chimtala 500 kV Transmission Line

This 500 kV transmission line from Pul-e-Chomri to south of Kabul via the "Bamyan Route" (alternative to Salang Pass) will pass by the Afghan coal deposits in Samangan and Bamyan and will further cross the area of the Hajigak iron deposit. Routing the line along this resource corridor will support power evacuation from the coal-fired power plants expected to be erected in that region in the course of the iron and copper mining project. Furthermore, the line will ensure power supply to the Hajigak iron mining project. Its total length is 316 km.

The line route traverses approximately 50 km of cultivated lands in the often narrow valleys. It is expected that a maximum of 150 towers will have to be located on arable land, so that owners and land users will have to have their property expropriated and be compensated. Land expropriation needs are estimated to be 1.5–2 ha for the entire line. If all social mitigation measures are implemented in the design, for example avoiding settlement areas, the resettlement impact will most probably be less than 150 households. Due to the geographical setting, lines can be spanned over valleys to provide sufficient safety clearances to houses and comply with EMF limit values. An IEE will have to be prepared, O.P. 4.12 is triggered and ADB safeguards on involuntary resettlement are triggered (SPS 2009). A detailed LARP will have to be developed after finalizing the line design on the basis of a detailed land survey.

A Local Area Development Plan (LADP) should be worked out and implemented in the framework of the project for all affected villages along the line. Priorities and activities of the LADP should be defined with the participation of the affected population. It is noted that the transmission line will be 500 kV and thus have no direct benefits in terms of electricity access for the local population.

9.2.5.2.3 Dasht e Barchi - Kandahar 220 kV Transmission Line

The proposed NEPS-SEPS Connector is an approximately 481 km single circuit (S/CKT) 220 kV transmission line from the proposed Dasht-e-Barchi substation to the proposed Kandahar East substation. With preliminary line routing resettlement requirement of the transmission line construction project is considered to be high as all houses would have to be removed from a 40 m corridor due to EMF safety considerations. Especially in the towns of Ghazni, Qalat and Kandahar, resettlement requirements would be high if the present line routing is maintained. With this amount of necessary displacement, the project would most probably have to be considered as Category A.

For final line routing, the Consultant recommends bypassing all settlement areas, even if this involves shifting the line further away from the main road and making construction of several additional angle towers necessary.

In Ghazni, at less than 200 m the preliminary line route is very close to the airport. The line would need to be shifted around the town.

If all social mitigation measures are implemented in the design, for example avoiding settlement areas, the resettlement impact will most probably be less than 200 persons, as sufficient land is available to provide bypasses and deviations of the transmission line. O.P. 4.12 is triggered and ADB safeguards on involuntary resettlement are triggered (SPS 2009). A detailed LARP will have to be prepared after finalizing the design.

9.2.5.2.4 Pul-e-Chomri Converter Station (500 kV/220 kV)

The new Pul-e-Chomri Converter Station is planned to be built near the site of the existing substation (35°58'26.08''N, 68°42'52.10''E). Two new 500 kV transmission lines will terminate there. The converter station is planned on semi-arid barren land without settlements and agricultural use. Social impacts of the substation are mainly related to the construction phase (e.g. workers camps, health and safety, moderate pollution) and are to be addressed in the EIA/ EMP. The land is state property and normally no expropriation of land or land acquisition is needed. There are no resettlement requirements and no impacts on indigenous people. There is sufficient space for in-feed lines so there will be no need for resettlement needs. The project is assessed as Category B.

9.2.5.2.5 Dasht-e-Barchi Substation (220/110/20 kV)

Dasht-e-Barchi substation will be located to the south of Kabul, about 15.9 km from Chimtala substation at GPS coordinates 34°28'25.45"N, 68°56'57.87"E. The substation will be located near the A1 road on barren land that is state property. Social impacts of the substation are mainly related to the construction phase (e.g. workers camps, health and safety, moderate pollution) and are to be addressed in the EIA/ EMP. The land is state property and normally no expropriation of land or land acquisition is needed. The in-feeding lines can access the substation site without the need for resettlement as the area is largely unpopulated. The access road to be constructed should be mounted so as not to damage cultivated fields. There are no resettlement requirements and no impacts on indigenous people. The project is assessed as Category B.

9.2.5.3 Thermal power plants

9.2.5.3.1 Sheberghan 200 MW CCPP

The planned gas-fired combined cycle power plant (CCPP) in Shebergan will be located in the desert area near the Shebergan substation (36°33'18.50"N, 65°42'47.50"E). The plant would be located between the city of Sheberghan and the 220 kV substation connecting Sheberghan with the Turkmenistan grid. The gas will be supplied from the Yatim Tagh gas field located about 15 km from the site. Some land acquisition will be necessary for the gas pipeline and the plant site. As the site is located in the desert, it is assumed that this problem will be modest. Health and safety issues during construction and operation related to air and water pollution will be the most important social impacts of the power plant. These are to be mitigated according to the EMP to be established and implemented.

It is unlikely that any compensation for loss of land and property will have to be paid, depending on the exact location of the plant. Residential housing close to the plant should be avoided. A full EIA is required for this plant (Category A project by definition). Depending on its exact location and the alignment of the pipeline, a Land Acquisition and Resettlement Plan may be needed.

It is not possible to install a 200 MWe gas-fired power plant at the present gas production rate. New wells have to be drilled for which social and environmental impacts must be assessed.

9.2.5.3.2 Ishpushta 400 MW Coal-Fired TPP

A 400 MW coal fired thermal power plant is planned at Ishpushta in Bamyan Province at the coordinates 35°18'57.00"N, 68° 4'33.00"E. It is intended that this plant will supply the copper mine at Aynak (34°22'60.00"N, 69°23'0.00"E) with electricity. The exact location of the coal mine is not known to the Consultant. The agreement was signed a few years ago with a Chinese contractor, providing for 50/50 power sharing between the mine and the national grid. Accordingly, 200 MW shall be fed into the Afghan grid. The planned Pul-e-Chomri-Chimtala transmission line will take the "Bamyan Route". Realization of this power plant project is not expected before 2027. It will supposedly have no land acquisition resettlement component. Potential social impacts from construction and operation of the power plant are mainly related to health and safety issues that will be mitigated through the EMP.

A mining plan with cost estimate for the coal is needed to prove the feasibility of the power plant fired with domestic coal. During the construction phase a workforce of about 2000 skilled workers, many of them expatriates, is needed. Huge amounts of building material and heavy special machinery have to be transported by truck. Social (and environmental) impacts from coal mining will have to be studied in the Coal Mining Plan. As a 50% share of the generated electricity is projected for use at Aynak Copper Mine, the downstream impacts of copper exploitation may have to be considered.

A full EIA is required for this Category A project. A resettlement plan may not be required, depending on the exact location of the power plant and its infrastructure.

9.2.5.3.3 Dara-e-Suf 800 MW Coal-Fired TPP

An 800 MW coal fired thermal power plant is planned at Dara-e-Suf in Samangan Province at the coordinates 35°39'60.00"N, 67°14'0.00"E. It is intended that this plant will supply the iron ore mine at Hajigak (34°40'4.09"N, 68° 1'58.70"E with electricity. The exact location of the coal mine is not known to the Consultant. The agreement was signed a few years ago with a Chinese contractor providing for 50/50 power sharing between the mine and the national grid. It is planned to connect it to the Pul-e-Chomri - Chimtala 500 kV transmission line.

The project will most likely have no land acquisition resettlement component. Potential social impacts from construction and operation of the power plant are mainly related to health and safety issues that will be mitigated through the EMP.

A mining plan with cost estimate for the coal is needed to prove the feasibility of the power plant fired with domestic coal. During the construction phase a workforce of about 2000 skilled workers, many of them expatriates, is needed. Huge amounts of building material and heavy special machinery have to be transported by truck.

A full EIA is required for this Category A project. A resettlement plan may not be required, depending on the exact location of the power plant and its infrastructure.

9.2.5.4 Hydro power plants

9.2.5.4.1 Gulbahar / Panjshir 1 120 MW HPP

Gulbahar HPP (also called Panjshir 1) storage project is situated at 35°10‘N, 69°17’E on the Panjshir River (Upper Panjshir Gorge) with the dam site about 3 km upstream of Gulbahar town. The project catchment area is 3,565 km^2 and the mean annual inflow 56 m^3/s. A rockfill dam of 180–200 m height and a crest length of 420 m will create a reservoir about 17 km long and inundate an area of about 13 km^2. If the dam is constructed at 1660 masl at the base, the reservoir water level would reach maximum of 1840 m. The planned installed capacity is 4×30 MW. The reservoir is planned in the rather narrow Panjshir valley with several larger villages and orchards and intensively cultivated fields in the valley bottom and hillsides.

The planned Panjshir 1 HPP reservoir will inundate most villages in the valley up to the village of Khwaja and most of the agricultural land as the arable land is mainly situated in the valley bottom. If the dam site is constructed at 1640–1660 masl at the base, a 180–200 m high dam would bring the reservoir level to a highest regulated water level (HRWL) of 1840 masl, a 80–100 m high dam to 1740 masl. Both alternatives would flood the recently re-constructed access road into the valley. LAR impacts of the alternative 1840 masl are expected to impact more than 2000 households. The small town of Tawakh would be inundated. It is difficult to estimate the number of people that would lose their agricultural livelihood base, but is expected to be substantially higher. Resettlement requirements for more than 10,000 people are expected. Most of the valley`s mining industry would be inundated by the reservoir up to the village of Khwaja. At an HWRL of 1740 masl LAR impacts are reduced, but are still expected to be substantial. It is estimated that 300–450 households would then have to be displaced. Impacts on the mining industry are less but still considerable in the lower part of the valley up to Tawakh. Below HWRL 1700 masl almost no settlements would be affected and losses of agricultural land would be considerably lower.

9.2.5.4.2 Baghdara 210 MW HPP

The Baghdara reservoir and power plant site is located at 34°49'58.70"N, 69°34'41.53"E on the Panjshir River (part of the Kabul River Basin) downstream of Gulbahar. The catchment area is approx 10,850 km^2, and the mean river flow 99.1 m^3/s, with the highest flow in June for a mean of 351.5 m^3/s and the lowest in January at 29.8 m^3/s. A dam of 90 m height and crest length of 125 m is planned, 4 km downstream of Alekozi. At the planned HRWL of 1460 masl, the reservoir will cover about 33 km^2, and reach up to the confluence of the Panjshir and Ghorband Rivers in the plain of Bagram. The reservoir will serve for seasonal storage and so also improve the output of the downstream run-of-river hydropower plants.

The Baghdara HPP has an important LAR impact at HRWL 1460 masl and 1440 masl as the reservoir would extend into the Bagram / Gulbahar plain, that is densely populated and intensively cultivated. It is expected that 10,000 to 20,000 people would have to be displaced and even more would lose their agricultural livelihood. Even at 1420 masl, the resettlement and land expropriation impact is still considerable, but below 10,000 AP. Only at 1380 masl would the reservoir not give rise to substantial resettlement and inundation of agricultural land, as it would be confined to the Lower Panjshir River Canyon. Planning of Baghdara HPP in combination with Capar HPP to maximize the use of the unpopulated canyon seems justified from a socio-economic perspective.

9.2.5.4.3 Surubi 2 180 MW RoR HPP

This hydropower project is located at 34°30'30.74"N, 69°57'0.14"E downstream of Surubi 1 HPP, so uses its discharge. The plant with an installed capacity of 180 MW and average energy production of 890 GWh, is planned at an elevation of 970 masl and will discharge through an 18.9 km tunnel to a tailrace at an elevation of 770 masl.

The Master Plan 2004 states that no settlements will be impacted by the project as it is located in a barren valley with no settlements and no agriculture. Neither arable land nor valuable vegetation or forest will be impacted.(Power Sector Master Plan 2004)

However, a few road side stalls and temporary settlements are traversed by the road and may be impacted at places where the road will need to be reconstructed due to the regulation reservoir. These buildings and loss of businesses will have to be fully compensated and affected persons relocated.

The Kabul- Jalalabad road will have to be reconstructed in certain areas. Traffic will be hindered during the construction period.

A full EIA will be required for this Category A project.

A Land Acquisition and Resettlement Plan (LARP) will be necessary if roadside settlements and market stalls are impacted and have to be relocated. However, the number of affected people is not expected to rise beyond 200 persons and these will only be temporarily affected during construction of the new road.

The project will presumably not be in conflict with any international agreements or principles of transboundary water systems. A notification to Pakistan is needed to comply with the International Waterways Directive.

9.2.5.4.4 Kunar A 368 MW Storage HPP

The planned HPP site is located at 35° 4'34.76"N, 71°21'56.59"E on the Kunar River, about 7 km upstream of Asmar, close to the village of Sangar. The drainage area is approx. 19,960 km^2 and the mean annual flow 370 m^3/s. The Kunar River originates in Pakistan and crosses into Afghanistan at the village of Barikov around 39 km upstream of the dam site in Shal/Kunar (Kunar A). The plan is to construct a 160 m high earthfill dam, with a crest length of 1080 m. The crest elevation will be at 1017 masl (HRWL). The reservoir will be about 26 km long. The power plant will utilize a head of 120 m in four units each of 91.5 MW.

The Kunar A HPP dam site is situated at 922 masl. The RoR HPP Project Kunar B at 35°9'56.95"N, 71°25'18.36"E is located at 960 masl, around 14 km upstream of Kunar A. The Pakistan border is at 1060 masl. The reservoir end point at 1017 masl is 26 km upstream of the dam site of Kunar A and 1.5 km downstream of Nari village, situated at 1030–1050 masl.

Kunar A HPP has a considerable LAR impact as the Kunar valley would be flooded along a length of approximately 25 km. All agricultural terrain in the valley and all settlements below HRWL 1017 masl would have to be expropriated and resettled. The entire valley is intensively cultivated in terraces. Steeper slopes are often forested. Additionally, the valley is used as a winter settlement area for Kuchi Nomads.

The project has a substantial resettlement and land acquisition component and will most probably affect more than 10,000 persons. Alternative land does not seem to be easily available in the near project area. New roads and other infrastructure have to be constructed.

The main access road into the valley will be inundated by the reservoir and will have to be replaced.

There is a mining and quarrying industry in the affected area. A military camp is located just above the upper end of the reservoir at 1030 masl.

A full EIA and detailed Land Acquisition and Resettlement Plan (LARP) will be required for this project. A careful assessment must be made of whether an Indigenous Peoples Development Plan is needed.

Full livelihood restoration including appropriate resettlement sites and full participation of all affected APs is required for this project.

Developing the Kunar A option would require reaching an agreement with Pakistan, which may include maintaining a prescribed monthly flow in the Lower Kabul River as it passes into Pakistan.

The project is located on a river that is so far unregulated.

Additionally, according to the World Bank (2010) there are plans from Pakistan to construct an HPP with a reservoir of live storage of about 715m m^3 and 150 MW of installed capacity, upstream on the Kunar River. An agreement with Pakistan is seen as critical for the project. The International Waterways Directive will apply.

A Local Area Development Plan (LADP) with a special focus on promoting gender equality should be included in the project.

A Peace and Conflict Assessment (PCA) should be developed for the project.

Presently, the site of Kunar B HPP is located within the reservoir of Kunar A. The compatibility of the Kunar A and Kunar B sites should be reviewed. More detailed planning is necessary to screen LAR impacts at greater depth.

9.2.5.4.5 165 MW Kunar B HPP

The Kunar B hydropower project is located at 35° 9'56.95"N, 71°25'18.36"E on the Kunar River about 22 km upstream of Asmar. It has a regulation reservoir with a storage capacity of 7.0m m^3 and an earthfill dam of height 105 m. The project is situated 14 km upstream of the Kunar A dam site and 25 km downstream of the PAK-AFG border.

The development of the hydropower potential of the Kunar River requires an integrated trans-boundary approach as there are also plans to construct an HPP further upstream on the Pakistan side. (see Kunar A)

With regard to capacity, there are some inconsistencies. Whereas the Power Sector Master Plan (Norconsult-Norplan, 2004) indicates that the installed capacity is 165 MW (3 x 55 MW) the National Energy Supply Program (NESP 2012) states that the installed capacity is 300 MW. The Main Invest Opportunities in Afghanistan (Afghanistan Investment Support Agency 2009) stated that the hydropower production potential of the Kunar river basin is 300 MW (Kunar B-Sagai) in the first stage and 900 MW (Kunar A-Shal) in the second stage. The World Bank Report (Scoping Strategic Options for Kabul River Basin 2010), locates the Kunar B project downstream of Kunar A with a capacity of 81 MW as an RoR HPP.

At the present location and with a planned height of 105 m, the Kunar B dam (HRWL 1070 masl) would flood the upper valley of the Kunar River into the territory of Pakistan.

The impact on land acquisition and resettlement is expected to be considerable. Most villages would be flooded except Shahmaser Narai and Barikov. The village of Nari and the military base 1.5 km downstream would be inundated.

The road from the dam site to the border of Pakistan would be inundated by the reservoir and would need to be replaced in difficult terrain.

The project is expected to have a substantial resettlement component. Alternative land does not seem to be readily available in the near project area. New roads and other infrastructure like bridges, quarries, a military camp etc. would have to be replaced.

A full EIA and a detailed Land Acquisition and Resettlement Plan (LARP) will be required for this project. Designing the project Kunar B as a run-of-river HPP situated below the site of Kunar A (World Bank 2010) would probably decrease the social impact.

A Local Area Development Plan (LADP) with a special focus on promoting gender equality should be included in the project.

A Peace and Conflict Assessment (PCA) should be developed for the project.

The International Waterways Directive will apply. Like for Kunar A, an agreement with Pakistan is regarded as critical for the Kunar B project.

9.2.5.4.6 Kama 45 MW RoR HPP

Kama HPP is located on the Kunar River immediately upstream of its confluence with the Kabul River. The project location that was communicated is 34°24'N, 70°34'E, which is directly in the flood plain at the confluence of the Kunar and Kabul rivers. An existing diversion weir is located between two hills at 34°27'32''N, 70°33'00''E, a few km further upstream on the Kunar River. The catchment area is 25,950 km^2 and the annual mean inflow is

484 m^3/s. It is primarily an irrigation project and the power plant will exploit the head of the main irrigation channel. The headrace channel will be 16 km long and the rated head is 85 m.

The confluence of the two rivers is located on a wide, flat river plain with branching river arms and extensive sandy areas. On a slightly higher elevation is a large flat plain with dense habitation and intensive agriculture. The project will provide irrigation water for this area.

Due to its planned location in a densely populated flat area, the construction of the power plant and irrigation/headrace channel will result in some land consumption and displacement of people.

According to the Power Sector Master Plan 2004, the project is planned as an additional facility for an irrigation project. Both the irrigation and power elements will operate on a run-of-river basis. The power element is not expected to have any impacts on the downstream river flow. The use of water for irrigation will lead to some reduction in the available water downstream.

The World Bank assesses, that "if security and access issues prevent the Kunar River storage (Kunar A) option from being considered for a considerable time in the future, then Kama, the farthest downstream site on the Kunar River, should be given high short-term priority. However, as the Kunar River valley widens as it approaches the Kabul River, and is intensively cultivated, even a low-head, run-of-river option at this site may involve substantial resettlement". (World Bank 2010)

Resettlement of houses and compensation for lost land and property will be necessary, however due to lack of data (no precise location of the planned dam has been communicated) this cannot be specified.

The project will require a full EIA and a detailed Land Acquisition and Resettlement Plan (LARP), with triggering of ADB SPS Involuntary Resettlement and OP. 4.12.

The International Waterways Directive will apply, as the river originates from and drains into Pakistan.

A Local Area Development Plan (LADP) with a special focus on promoting gender equality should be included in the project.

9.2.5.4.7 Kajaki 2 100 MW extension storage HPP

Whereas all previously considered HPPs are located in the Kabul River Basin, Kajaki HPP is located on the Helmand River, 95 km northwest of Kandahar City at 32°19'22.73"N , 65°6'57.59" E. Most social impacts would arise in the Deh Rahwod district along the Helmand River in Oruzgan Province. The ethnic groups in the district are Paschtu, dominated by the Noorzai and Populzai sub-groups.

Kajaki HPP has a regulation reservoir with a storage capacity of 1.7m m³. The rockfill dam was constructed in 1952 for irrigation purposes. The present dam height is 98 m. The project aims to increase the active storage capacity from 1.7m m³ to 2.7m m³. The project also proposes installation of a second power house to generate 100 MW.

According to the Power Sector Master Plan (Norconsult-Norplan, 2004), "plans were approved in the late 1970s for installation of 11 m high radial gates in the spillway, and increase dam height by 2 m. This would increase reservoir elevation from 1037 masl to 1048 masl".

However, the present reservoir level is 1011 masl. According to the Power Sector Master Plan 2004 there were different initial plans for the reservoir (HRWL 1037 masl), but it appears that the reservoir level has never exceeded this mark and the land further up the Helmand River is cultivated and populated. The extension of Kajaki 2 HPP inducing a rise of the reservoir level does not involve substantial resettlement up to HRWL 1022 masl. Beyond an HRWL of 1022 masl, the LAR impacts in the Helmand river valley (reservoir inflow) are considerable, amounting to several thousand households at HWRL 1048 masl. From a socio-economic perspective, it is expected that at this level (1048 masl), the majority of people up to the district town of Deh Rawod would lose their home and/or agricultural livelihood base.

A full EIA is required for the project as it is Category A.

A detailed Land Acquisition and Resettlement Plan (LARP) including intensive public consultations and establishment of resettlement sites is needed. Resettlement Safeguards (SPS 2009) and OP 4.12 are triggered by the project.

A Local Area Development Plan (LADP) with a special focus on promoting gender equality should be included in the project.

Presently, the area is a conflict zone, reputedly a Taliban stronghold, including recent attacks and social unrest. According to the mine clearing center (MACCA) known mine infested areas have been cleared in the district.

A Peace and Conflict Assessment (PCA) should be developed for the project.

9.2.5.5 Renewable energies

Within the context of this study, renewable energies (RE) comprise energy generated by wind, the sun, geothermal energy and from biomass. Energy from hydropower plants has been discussed separately. The current use of renewable energy sources for electricity generation (apart from hydropower) is very limited within Afghanistan (see section 5.1.3). At the moment there are basically no central power plants that utilize renewable energies like solar, wind, biomass or geothermal. The available sources with the greatest potential are solar and wind.

However this potential is promising. According to a study by USAID, a 30 MWp PV plant in Kandahar area would reduce diesel consumption of the generators located in Bag-e-Pol and Industrial Park by an estimated 48%, or US$15.6m annually. (Source USAID, June 2012)

A comparison of typical decentralized systems with diesel only, a hybrid system consisting of diesel and PV, as well as a diesel and a small wind turbine is presented in section 6.1.3.

Small-scale decentralized renewable energy structures could also be promoted within the Local Area Development Plans (LADP).

9.2.5.6 Rural electrification

Rural electrification is an important element to reduce poverty in areas where 80% of the Afghan population and most Project Affected People live. Whereas centralized energy development is important for the quickly growing urban population and its rising energy demand as well as for the needs of the developing industries, small-scale decentralized renewable energy options meet the needs of the poor, particularly dispersed populations in rural areas, more effectively than centralized infrastructure.

The International Center for Integrated Mountain Development (ICIMOD) promotes such an approach in the context of Afghanistan "as it is less damaging to the environment, and can be developed on a basis that is financially, institutionally, and environmentally sustainable. It would allow communities to identify their own needs and create the conditions necessary to make efficient use of local energy resources (micro hydro, solar, biomass, wind, others), as well as develop indigenous manufacturing and technical capability". (Source ICIMOD 2009)

Decentralized energy development focuses on island projects under the master plan. A comparison of typical decentralized systems with diesel only, a hybrid diesel and PV system, and a hybrid diesel and small wind turbine is presented in section 6.1.3.

From a socio-economic perspective, decentralized energy development with a focus on rural electrification would contribute substantially to reducing poverty in Afghanistan and should be vigorously pursued. There are several organizations and international donors promoting this approach. Donor coordination in this regard is recommended.

9.2.5.7 Preliminary estimate of social mitigation costs

Preliminary cost estimates are only possible in part due to a lack of data, exact project definitions and information from (at least) preliminary AP censuses and inventory of losses.

(i) For the transmission line projects, social mitigation costs (LAR) are estimated to be:

- TKM border-Shebergan SS: $250,000–300,000, the line section Shebergan SS- Pul-e-Chomri has not yet been designed
- Pul-e-Chomri SS-Chimtala SS: $2–4.5 million, with present line routing and a decrease depending on resettlement requirements with design and line routing mitigation potential

- Dasht e Barchi SS-Kandahar SS: $2.5–4 million, with present line routing and a decrease depending on resettlement requirements and design mitigation potential

(ii) For SSs and TPPs, no social mitigation costs are expected over and above the provisions in the EMP.

(iii) For HPPs, a more detailed assessment of the resettlement requirements with demarcation of reservoir level, AP census and inventory of losses including livelihood resources is necessary in order to prepare a realistic cost estimate. An exception will probably be Surobi HPP with an estimated social mitigation cost of approximately $100,000 to compensate for or reinstall several market roadside stalls if these are affected.

9.2.6 Conclusion

As stated in the introduction to this report, the reason for including social aspects when planning power projects is to increase the chances of selecting those that are socially sustainable and modify project planning to avoid or minimize social impacts. At an early stage in planning, high negative environmental and social impacts can still be avoided or minimized by design, which is a priority in project development under international safeguards.

ADB Safeguards Policy Statement (SPS 2009) and the relevant World Bank Operational Policies (OP) 4.01, 4.07, 4.10, 4.11, 4.12, 7.50 are the guiding international safeguards with regard to mitigation of social impacts.

The general considerations and preliminary social screening of the selected projects of the Power Sector Master Plan (2012 update of 2004 document) reveal that the social impacts of energy infrastructure projects are mainly related to land use, land acquisition and resettlement issues (to be detailed in Land Acquisition and Resettlement Plans (LARP)) as well to as other Environment, Health and Safety (EHS) impacts that will arise during the construction and operation phases of the projects that are the subject of the Environmental Impact Assessment (EIA) and Environmental Management Plans (EMP).

Additionally, in the context of Afghanistan, conflict analysis and security considerations will be necessary. Peace and Conflict Assessments (PCA) should be considered for all projects. The heterogeneous population pattern with many ethnic groups, some of which may have to be considered as indigenous peoples, will in some cases lead to Indigenous Peoples Development Plans (IPDP).

Due to the geographical conditions in Afghanistan, most of the planned project will have Land Acquisition and Resettlement (LAR) requirements. Regarding LAR impacts, five categories of projects can be distinguished for this Master Plan:

a) The substations (SS) will have low LAR impacts, as the plot required is comparatively small at 2–4 ha per SS and project sites are situated in sparsely populated semi-arid areas.

b) Thermal power plant (TPP) projects will also generate very limited LAR impacts, as the land required is comparatively small and sites are situated in sparsely populated semi-arid areas. Ancillary infrastructure will have to be considered.

c) Transmission line (TL) projects will generate land acquisition requirements mainly at tower foundations although these impacts will be locally small at not more than 300–400 m^2 per km of TL and can be compensated in cash or in kind without destroying livelihoods. Access roads will also be needed in part and result in land requirements that could be significant, especially in steep mountainous terrain. The major impacts – apart from visual impacts that cannot be mitigated – are resettlement requirements from the safety corridor (RoW) due to electric and magnetic fields (EMF). All houses will have to be removed from the safety corridor and reinstalled outside the RoW, with full replacement of assets.

d) Run-of-river hydropower plants (RoR HPP) will generate moderate to medium resettlement and land acquisition needs as diversion weirs and regulation reservoirs will inundate some areas depending on the selected project site. Especially in flat, populated and cultivated areas, like for Kama HPP, LAR impacts are estimated to be considerable.

e) Storage reservoir hydropower plants (HPP) are expected to have high LAR impacts at the planned maximum reservoir water levels. Due to geographic features and the country's settlement and land use pattern , residential and agriculture areas are located at the bottom of valleys or in river plains. In areas where planned reservoirs extend into the river plains, these projects would affect large numbers of people, as the plains are intensively used for agriculture and are densely populated, i.e. upper part of Baghdara Reservoir above HRWL 1420 masl, upper part of Gulbahar/Panjshir 1 above HRWL 1700 masl, Kunar A and Kajaki 2 extension above HRWL 1022 masl. On the other hand, in areas where the planned reservoirs are confined to the steepest and narrowest parts of the river gorge, i.e. lower part of Baghdara Reservoir below HRWL 1380 masl, or Surobi 2 RoR (see above), social (LAR) impacts are expected to be low, with no settlements or cultivated fields affected.

In a multi-ethnic setting with conflict lines centered essentially around access and control over scarce resources like fertile land and drinking /irrigation water, suitable resettlement sites that would permit sustainable livelihood restoration are difficult to find. Conflicts with host populations and aggravation of existing conflicts are probable. From a socio-economic perspective and with regard to SPS (2009) and OP 4.12, sub-projects will have to be planned in detail to avoid resettlement as much as possible. This is especially relevant for hydropower projects with storage reservoirs, as these could potentially result in resettlement of ten-thousands of affected persons (APs).

Impacts on indigenous peoples and/or vulnerable ethnic groups may arise for Panjshir, Baghdara, Kunar A and Kajaki HPP, as the areas of the planned reservoirs are regularly used by the nomadic Kuchi population who depend on the land and resources for their winter camps and to graze their animals. The magnitude of the impact and the need to set up Indigenous Peoples Development Plans (IPDP) must be assessed in field studies on a case-by-case basis during the further project phases.

Resettlement and loss of an agricultural livelihood base result in vulnerability for both genders, but women as the main caretaker of the household may be even more severely affected by loss of access to the usual resource base. Positive gender impacts may be created through the implementation of gender sensitive Local Area Development Plans. LADPs need to include special provisions for vulnerable groups, which exist in all project areas.

Consultation of relevant stakeholders, affected population, the general public as well as civil society organizations is to be done in line with international safeguards (ADB / WB) during the entire project cycle and start as early during project preparation as possible. For all projects selected for the Power Sector Master Plan, but especially for hydro power projects, intensive public consultations should be conducted, including AP censuses and detailed inventories of losses (for HPP below a demarcated water line) to determine the magnitude of the social impacts and avoid resettlement as much as possible through adaptation of project design.

As the Kabul River Basin, including the Panjshir and Kunar Rivers, drains into Pakistan, downstream impacts have to be considered in a trans-boundary context. The policy on international waterways (Op 7.50) will be triggered for all HPP projects. A detailed Peace and Conflict Assessment is recommended, especially for the Panjshir, Helmand and Kunar River Valleys.

Construction of HPP dams will create a large number of temporary local jobs in the project areas and contribute to much needed cash income for the local population. A big influx of external construction workers, though, may also cause conflicts with local residents.

Screening of socioeconomic safeguard implications for the selected projects within this Power Sector Master Plan suffers from lack of detailed data from in depth field surveys and public consultations, which should be intensively carried out in the course of further planning. Nevertheless, it can be concluded that the most severe social impacts are related to the Land Acquisition and Resettlement (LAR) impacts of the planned storage hydro power plants. Appropriate mitigation measures by design should be implemented as project planning proceeds to avoid resettlement. At lower reservoir levels, most of the considered HPP projects have drastically less social impacts due to their geographic location. Full EIA and LARP procedures are required for all subprojects.

Generally, an upgraded electricity supply will contribute in various ways to improving living conditions and economic growth on a national scale, especially in a country like Afghanistan where the majority of the population does not have access to electricity.

Direct employment opportunities during the construction and indirect employment generation through industrial development may create additional income for the poor segments of the population and eventually trickle down to the project areas, especially in those areas where rural electrification is promoted and Local Area Development Plans (LADP) are implemented.

10. Optimization Model

This chapter describes the optimization model for least cost planning. The first subchapter gives an overview and describes the structure of the model using the methodology of reference energy systems (RES). Generally, we use diagrams and graphical visualization instead of extensive text descriptions wherever possible.

The second subchapter summarizes the relevant input data. A detailed discussion of these data is given in previous chapters. There are supplementary analyses for topics specific for least cost planning. Examples are time-dependent characteristics of demand and hydro generation together with the parameters required for evaluation of the overall system. Examples are discount factors, escalation factors for prices and valuation of fossil fuel deposits.

The third subchapter shows and discusses the results of the optimizations. This includes a detailed description of the base variant and differences for variations of demand (high case, low case) and discount rate.

The fourth subchapter analyses sensitivities and discusses additional issues arising from discussions during the project. It may include descriptions of additional findings and depictions of important dependencies and baseline conditions.

The fifth subchapter includes extended investigations of variants based on an optimistic time schedule for expansion of hydro and coal based generation units.

The sixth subchapter includes the recommendation for a robust strategy for future development of the Afghan energy system.

10.1 Overview and Reference Energy System Diagrams

10.1.1 Objectives and approach

Least cost planning optimizes the overall impact of the Afghan energy system on the welfare of Afghani citizens. On the basis of stated demand, the objective function is minimized with generalized cost coefficients factored in for all relevant decision variables. Constraints ensure compliance with the rules and the validity of the achieved solution. Key issues addressed are:

- cost-optimized strategies to satisfy projected demand at minimal costs
- identification of robust decisions under the given uncertainties
- identification of optimal decision points and flexibility of decisions in relation to main uncertainties.

The evaluation is carried out in five stages:

- model definition and identification of candidate projects, with decision variables
- preliminary analysis

- optimization and scenario analysis of remaining nonlinear dependencies
- sensitivity analysis
- recommendation for a robust strategy with roadmap.

Several issues as follows have to be considered in this process.

The model includes all **decision relevant costs**. Other costs are included depending on provided data and restrictions on the model size and its complexity. Costs dependent on capacity decisions are valued at the start of operation of the appropriate asset. Residual values are taken into account depending on the residual lifetime at the end of the planning period.

For the model, 2011 is defined as base year and, as requested, a 21 year planning period from 2012 to 2032 is considered. The available data sources reference in part data from other years and we had to make assumptions for the status of the power generation units at the base year.

Real terms: Costs and benefits are expressed in real terms in constant 2012 prices. CAPEX is net of any price contingencies up to the commercial operation date (COD), and general inflation is not considered in the projection of costs over the planning period.

Discount rate: Costs are (internally) set up as cash flows over the planning period and then discounted to their present values. A discount rate of 12% is used for discounting in the base variant, as is standard practice in projects involving funding from the ADB. Variants with discount rates of 9% and 12% have been calculated for the scenario analysis. Costs are expressed in constant market prices of 2012.

10.1.2 Overall system, area dependencies and grid connections

The following subchapter gives an overview of our model of the existing system (base year 2011) and the candidate options for electricity generation and for main network connections. Detailed data on existing units and candidates is described in previous chapters.

Besides the list of candidates for generation and transmission expansion, the results of the demand forecast exercise as well as the analysis of transmission constraints like for the Salang Pass will be taken as input data for system modeling and optimization.

The expected load demand per load region is discussed and described in the corresponding task.

Input data from existing power purchase agreements are discussed and described in the corresponding task.

The present status of the Afghan Power System is reflected in the optimization model by separate islanded areas, namely

- NEPS AFG
- NEPS UZB

- NEPS TAJ
- NEPS TKM
- SEPS
- Herat
- Nimruz

The grid segments are generally islanded segments. From detailed modeling of the restrictions of the Salang Pass, we defined an area to the south of the pass (NEPS Kabul UZB) and one to its north (NEPS UZB). The diagram below shows the grid segments, import lines and grid connections. Existing connections are shown black, candidates are red and dotted respectively for finalized projected grid connections and optional grid connections.

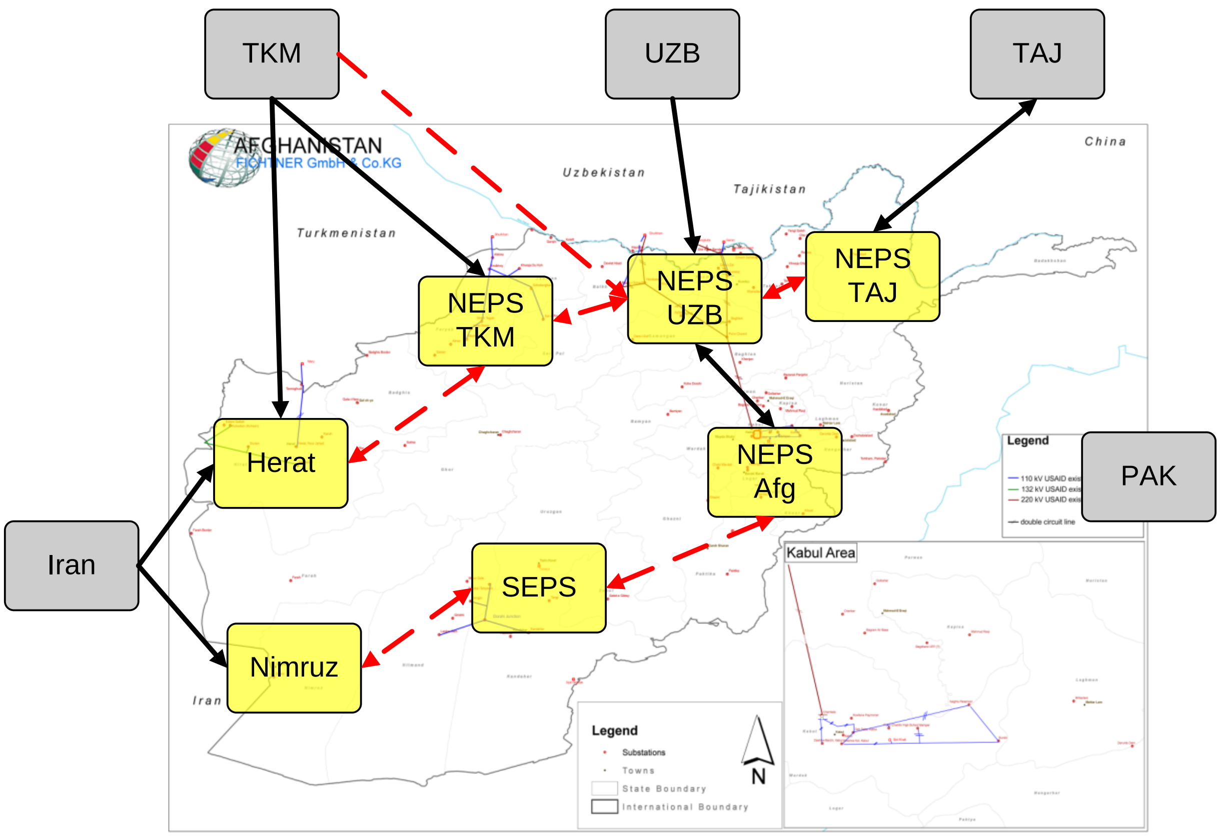


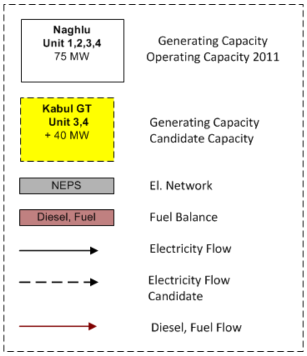
Figure 10.1.2-1: Grid segments and interconnections

At present, domestic electricity generation is based mainly on hydro power plants, diesel generator sets and diesel-fired thermal power plants. Afghanistan imports electricity from Uzbekistan, Tajikistan, Turkmenistan and Iran.

Integration of several independent parts and load regions improves controllability and system stability.

Strategies have to take into account that the present system is dominated by “non-commercial” aspects, like security. There is great uncertainty about possible changes in baseline conditions, even in the near future. Therefore the study will focus on robust strategies and identification of optimal decision points to ensure flexibility and support best possible the development of a controllable and stable overall system.

The following subchapters will show the subsystems per area as block diagrams.



Existing generation units (base year 2011) have a block description in white, stating site, unit, type and capacity. Generation unit candidates are identified by a yellow background and dashed outline.

Electricity flow is marked by black lines, with candidates marked as dashed lines.

Demand is shown as a white block.

Characteristics

The **existing system** (white) consists of isolated areas. It is dominated by high import capacities with low prices and seasonal dependencies, high hydro capacities with seasonal dependencies and high capacities of diesel-based generation with high specific fuel costs.

The **connection candidates** have been discussed in detail in previous chapters. Grid connection will have quantitative economic effects that are reflected in the model. Other, qualitative effects will result in a higher availability and robustness of the overall system.

Generation candidates compete with import options for electricity. Prices for import options are fixed over the short term, and are associated with long term risks and dependencies.

There are options for high additional HPP generation capacity. The seasonal behavior must be balanced. Generally main influence factors for balancing are seasonal behavior of demand, import/export options and hydro storage. Residual load has to be balanced by thermal generation capacity and hydro storage.

At the present stage of the analysis, gas-based thermal generation is superior to coal-based thermal generation.

Renewables (without hydro) are included in the model and, based on present input data, we do not expect that wind and PV will dominate the system as a whole.

10.1.3 NEPS AFG

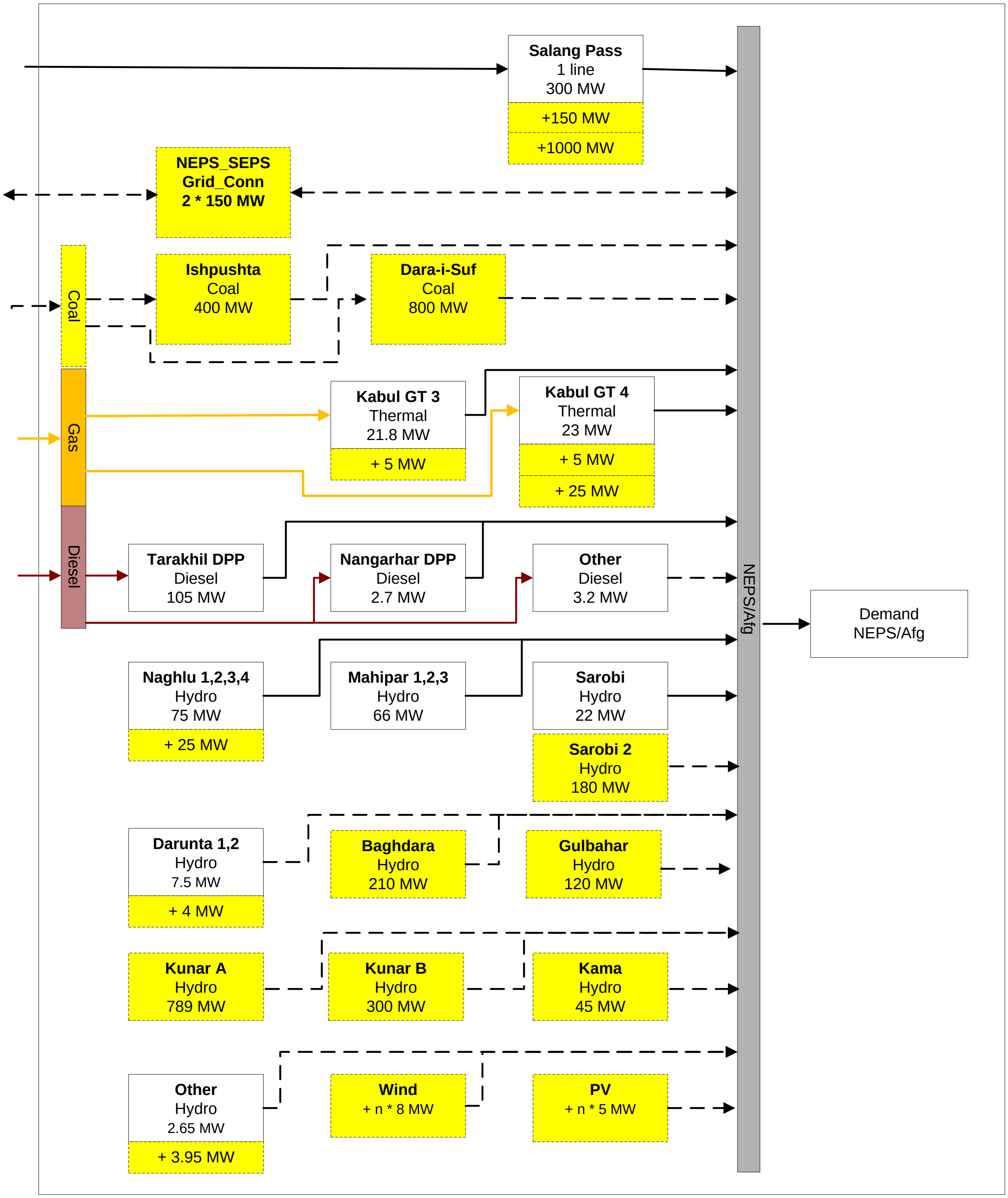


Figure 10.1.3-1: Model for NEPS AFG energy flow

Figure 10.1.3-1 shows the energy flow and dependencies of the NEPS AFG grid segment. Existing generation units, generation candidates and grid options are described in detail in the corresponding subchapter of chapters 5 and 6.

Small hydro units are aggregated to one block called “Other Hydro”. Small diesel units are aggregated to one block called “Other Diesel”.

Characteristics

The **existing system** (white) contains high generation capacities with hydropower plants (HPP) and diesel fired units. Diesel gives rise to high specific fuel costs. In conjunction with the seasonal variability of demand curves, the seasonal dependency of HPP generation will have significant effects on the overall system design. There are various isolated HPPs whose integration into the main grid will raise availability.

The **candidates** include very high HPP capacities and gas-fired units in Sheberghan. The HPP generation capacities must be analyzed in the overall system context. We anticipate energy economic restrictions from import options and restrictions due to seasonal behavior. Restrictions that may explain why some projects were not implemented in the past, like security aspects, are not included in the model. Generation from gas-fired units is independent of the season. For wind, we defined candidates with a block size of 10 MW and for PV we defined candidates with a block size of 5 MWp.

10.1.4 NEPS UZB and NEPS Kabul UZB

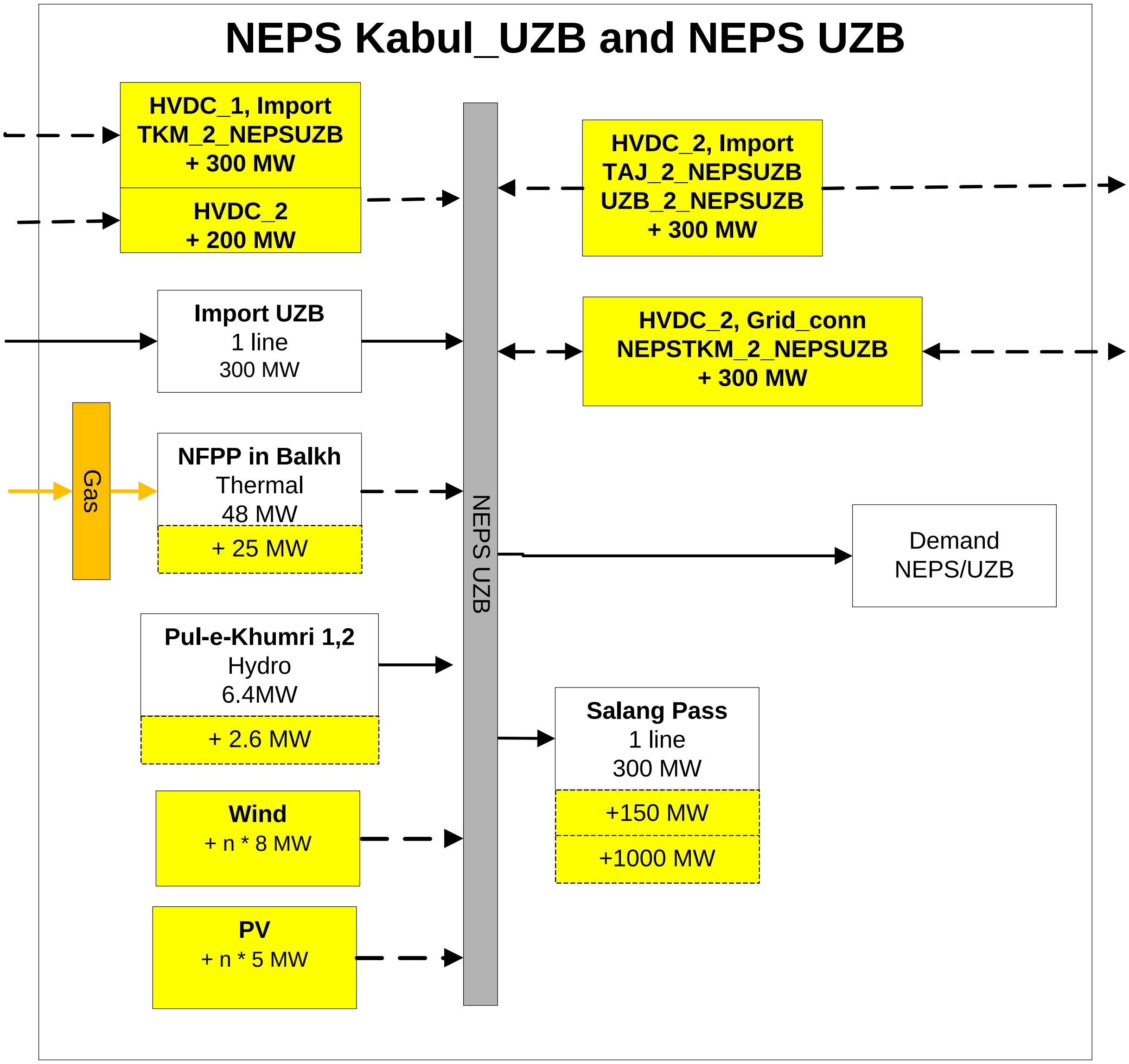


Figure 10.1.4-1: Model for the NEPS UZB and NEPS Kabul UZB energy flow

The Figure 10.1.4-1 shows the energy flow and dependencies of the NEPS Kabul UZB and the NEPS UZB grid segments. The existing generation units, generation candidates and grid options are described in detail in the corresponding subchapter of chapters 5 and 6.

<u>**Characteristics**</u>
The **existing system** (white) is based on import capacities from UZB. The Salang Pass restricts the energy transport capacity. The model includes two grid segments. The Salang Pass is modeled as a restricted transport capacity between these two grid segments. Demand is modeled per grid segment.

The **candidates** include grid options for additional energy transport capacity via the Salang Pass. The options for coal-based generation (Bamyan) are long term for which feasibility is uncertain. Two different block sizes are included, because specific costs and overall system behavior depends on block size. For wind, we defined candidates with a block size of 10 MW and for PV we defined candidates with a block size of 5 MW_p.

10.1.5 NEPS TAJ

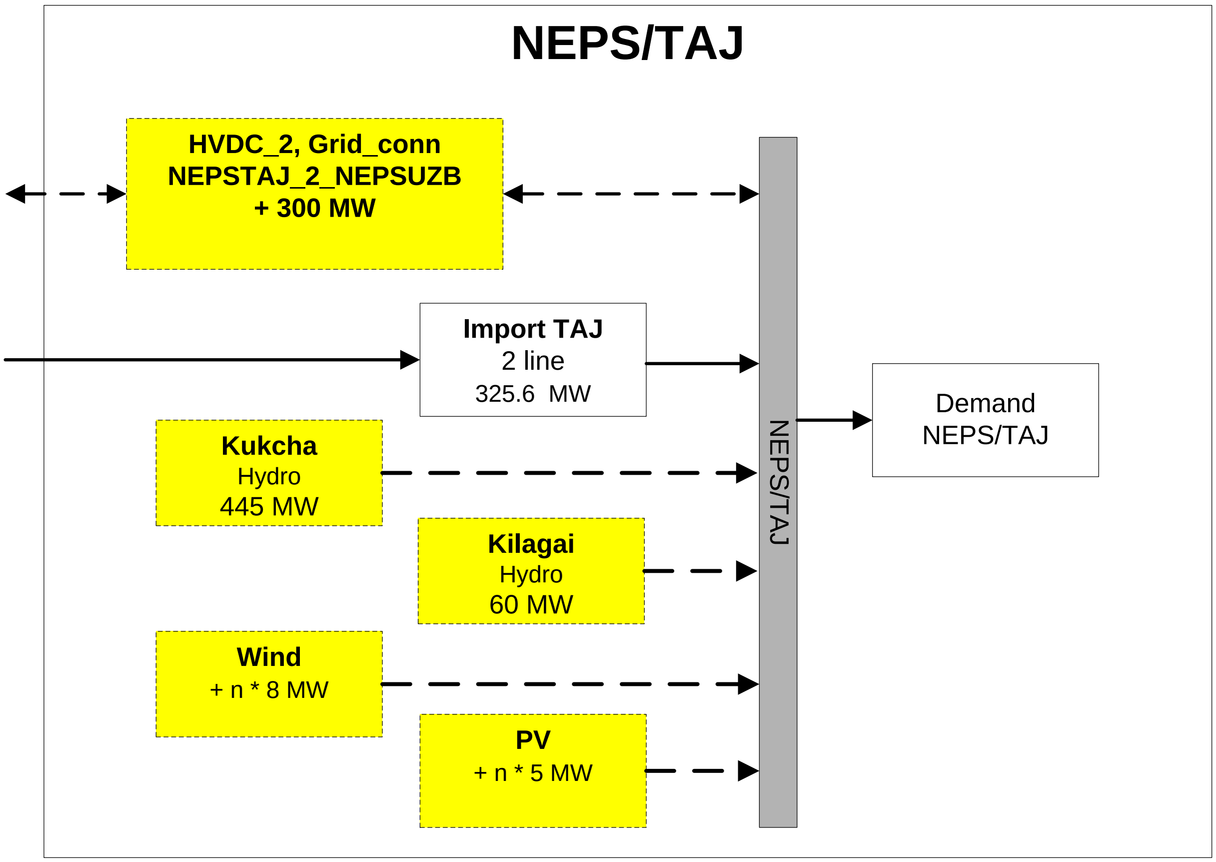


Figure 10.1.5-1: Model for the NEPS TAJ energy flow

Figure 10.1.5-1shows the energy flow and dependencies of the NEPS TAJ grid segment. The existing generation units, generation candidates and grid options are described in detail in the corresponding subchapter of chapters 5 and 6.

Characteristics

The **existing system** (white) is based on import capacities from TAJ.

The **candidates** include high generation options for two additional HPPs. The HPP candidates of the NPS AFG segment must be analyzed in the overall system context. For wind, we defined candidates with a block size of 10 MW and for PV we defined candidates with a block size of 5 MW_p.

10.1.6 NEPS TKM

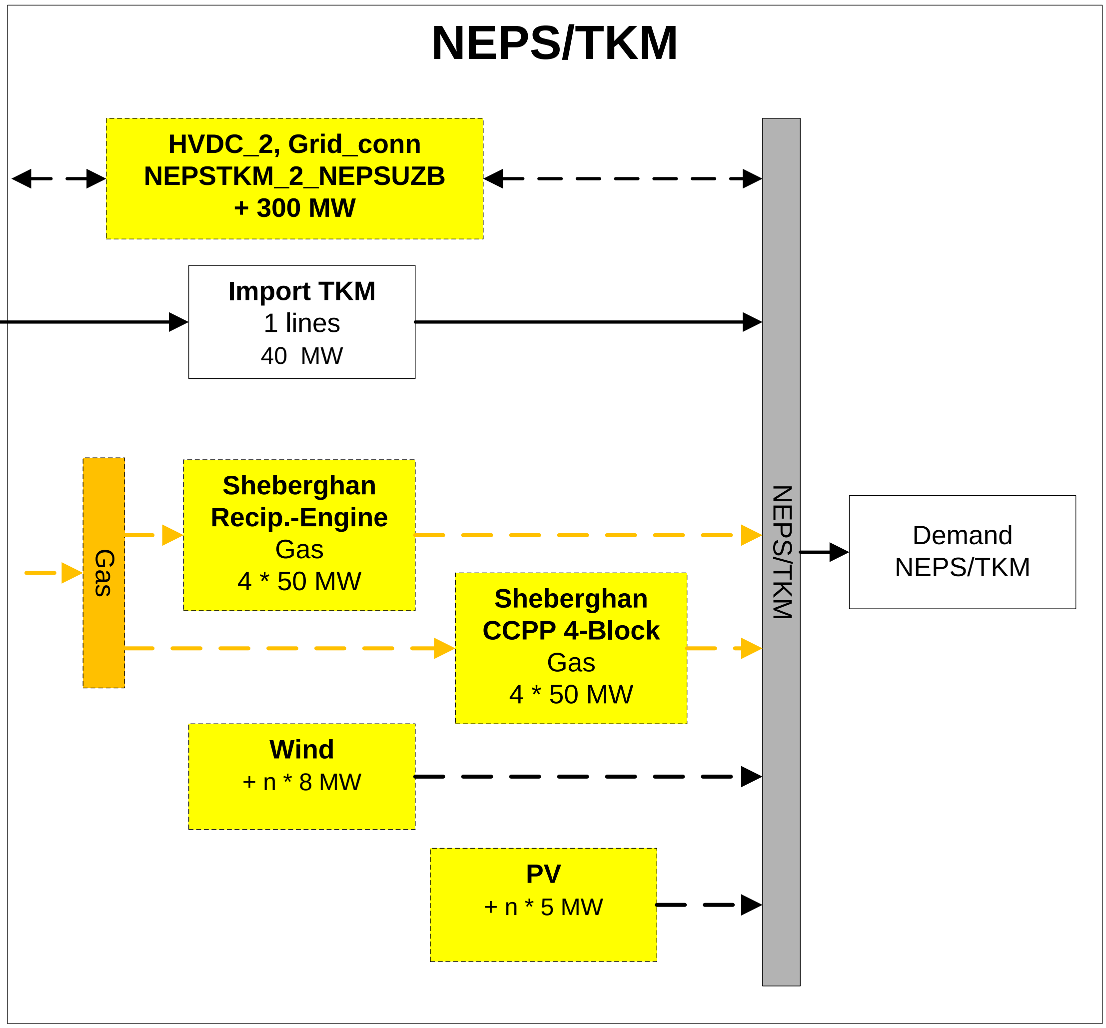


Figure 10.1.6-1: Model for the NEPS TKM energy flow

The Figure 10.1.6-1 shows the energy flow and dependencies of the NEPS TKM grid segment. The existing generation units, generation candidates and grid options are described in detail in the corresponding subchapter of chapters 5 and 6.

<u>**Characteristics**</u>
The **existing system** (white) is based on import capacities from TKM.
The **candidates** include additional import capacities, options for wind with a block size of 10 MW and options for PV with a block size of 5 MW_p.

10.1.7 SEPS

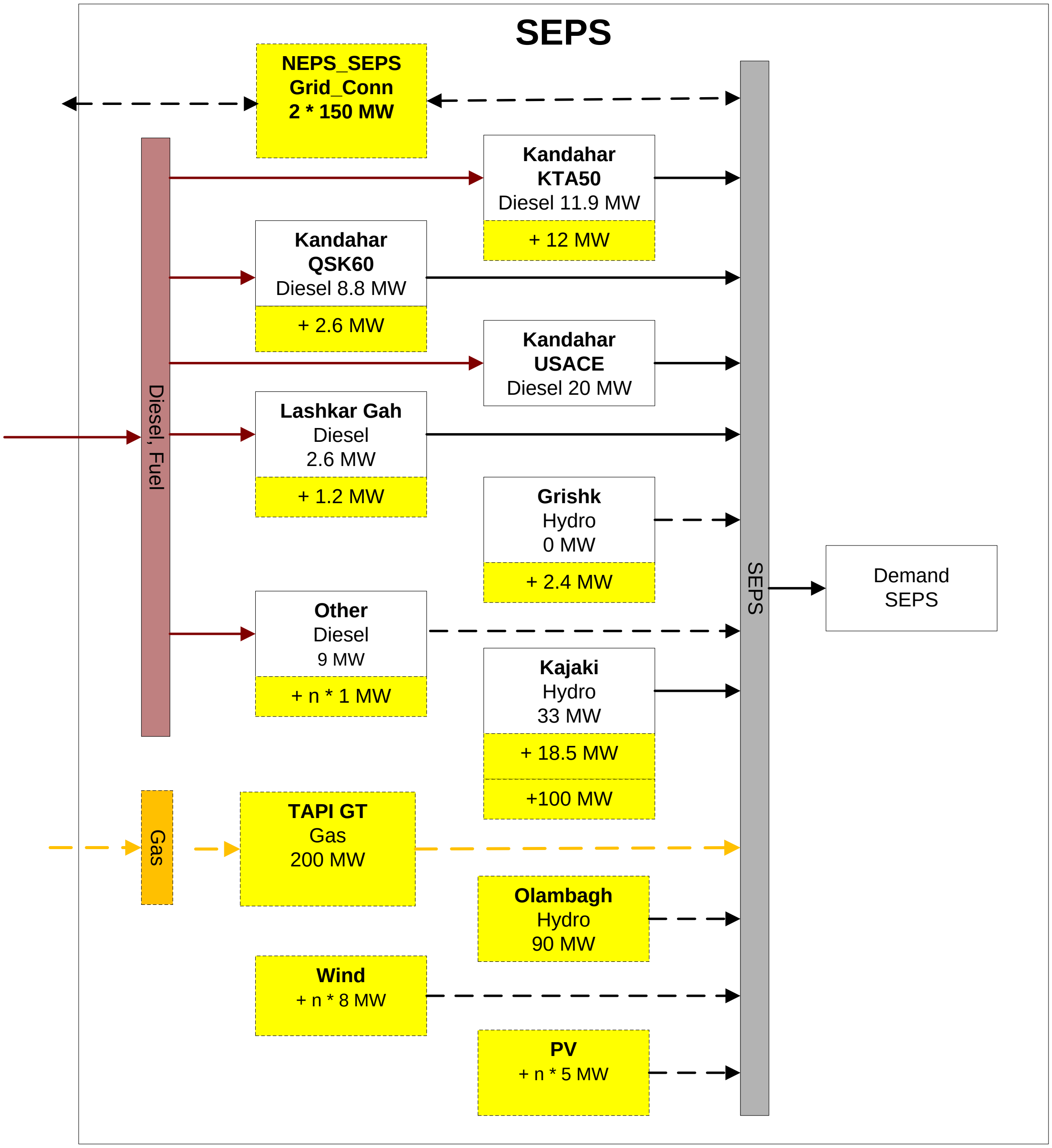


Figure 10.1.7-1: Model for the SEPS energy flow

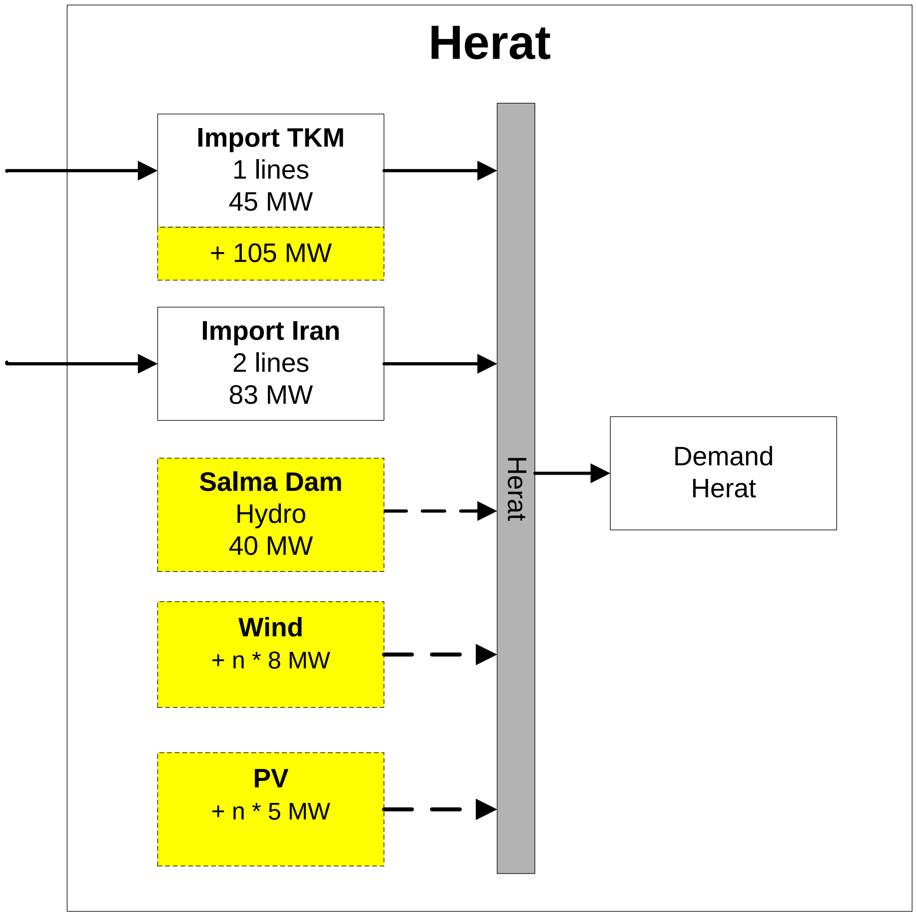
Figure 10.1.7-1 shows the energy flow and dependencies of the SEPS grid segment. The existing generation units, generation candidates and grid options are described in detail in the corresponding subchapter of chapters 5 and 6.

Small diesel units are aggregated to one block called “Other Diesel”.

Characteristics
The **existing system** (white) contains HPP and diesel-based generation capacities. Diesel gives rise to high specific fuel costs. In conjunction with the seasonal variability of demand curves, the seasonal dependency of HPP generation will have significant effects on the overall system design. There are various isolated HPP whose integration into the main grid will raise availability.

The **candidates** include high HPP capacities. The overall system includes a candidate for a connection between NEPS AFG and SEPS. The HPP generation capacities must be analyzed in the overall system context. We anticipate energy economic restrictions from import options and restrictions due to seasonal behavior. Restrictions that may explain why some projects were not implemented in the past, like security aspects, are not included in the model. For wind, we defined candidates with a block size of 10 MW and for PV we defined candidates with a block size of 5 MWp.

10.1.8 Other areas



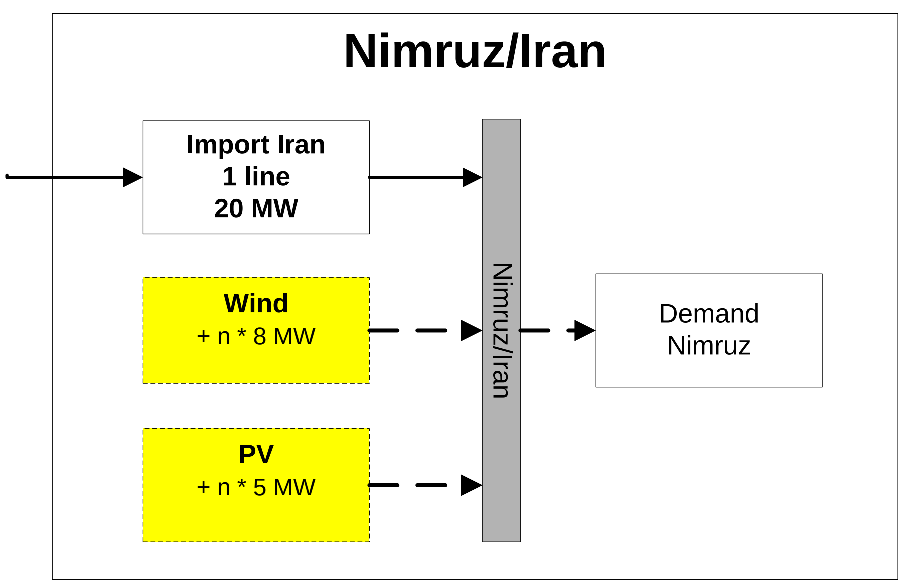


Figure 10.1.8-1: Models for the Herat TKM, Herat AFG, Herat Iran and Nimruz Iran energy flows

Figure 10.1.8-1 shows the energy flows and dependencies of the Herat TKM, Herat AFG, Herat Iran, Nimruz Iran grid segments. The existing generation units, generation candidates and grid options are described in detail in the corresponding subchapter of chapters 5 and 6.

Characteristics
The **existing system** (white) consists of two isolated areas. Generation capacity is provided via import lines from TKM and Iran.

The **candidates** include the Salma Dam HPP project and additional import capacities. For wind, we defined candidates with a block size of 10 MW and for PV we defined candidates with a block size of 5 MWp per grid segment. The candidates define two new areas / grid segments, including additional demand curves.

10.2 Input Data and Preliminary Analysis

10.2.1 Grid Segmentation

Grid Segment	Unserved Price	Price Escalation
	[USD/MWh]	[1]
Herat	8500	1.00
NEPS AFG	8900	1.00
NEPS TAJ	8700	1.00
NEPS TKM	8800	1.00
NEPS UZB	9000	1.00
Nimruz	8400	1.00
SEPS	8600	1.00

Table 10.2.1-1: Grid segmentation

We used seven grid segments, to incorporate imports and the main internal grid connections in the model. There are separate load flow calculations in the project and we use a simplified grid representation for capacity expansion planning. High prices for unserved energy force its minimization. A small variation of these prices prevents undefined shifts between grid segments.

10.2.2 Demand

Demand	Grid Segment	Characteristic	Projection
Herat demand	Herat	demand char	demand proj
NEPS AFG demand	NEPS AFG	demand char	demand proj
NEPS TAJ demand	NEPS TAJ	demand char	demand proj
NEPS TKM demand	NEPS TKM	demand char	demand proj
NEPS UZB demand	NEPS UZB	demand char	demand proj
Nimruz demand	Nimruz	demand char	demand proj
SEPS demand	SEPS	demand char	demand proj
Bamyan TPP demand	NEPS AFG	constant	demand fixed

Table 10.2.2-1: Demand curves, overview

The model includes one demand curve per grid segment. Based on the provided data we used the same characteristic for all demand curves. Individual scaling is done by the projections of the annual energy and the annual peak.

Following the latest discussions, we included an additional demand for copper and ore mines that are developed in conjunction with coal-fired power plants. We summarized this demand as Bamyan TPP demand. For this, we assumed a constant demand of 200 MW (copper mine) from 2027onwards and an aggregated demand of 600 MW (copper mine + ore mine) from 2029. The definition is shown in the table below.

Demand	From period	To period	Avg power
	[a]	[a]	[MW]
Bamyan TPP demand	2011	2027	0
Bamyan TPP demand	2027	2028	200
Bamyan TPP demand	2029	2032	600

Table 10.2.2-2: Constant demand for copper and ore mines

The following discussion analyses and explains the time characteristics of the demand. This time characteristic defines together with hydro characteristics the underlying time structure of the optimization model.

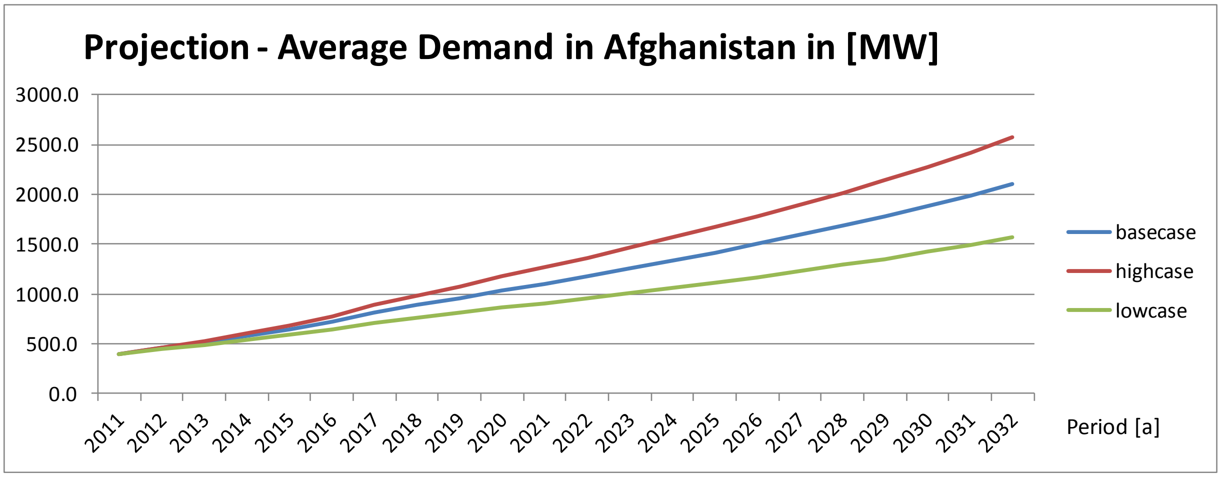


Figure 10.2.2-1: Demand Projections in [MW avg] for Afghanistan

The above graph shows the projection of the average demand of Afghanistan. There is a comparable projection of the peak load. A detailed discussion is given when deriving the demand projection in the above chapters.

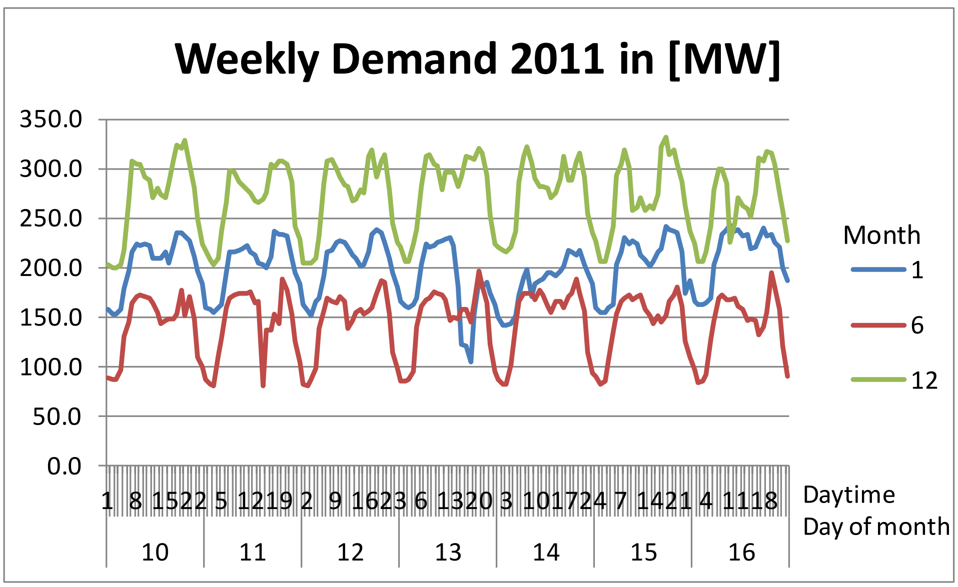


Figure 10.2.2-2: Weekly demand in [MW avg]

The above graph shows measurement data for electricity consumption around Kabul in 2011. It shows curves for one week each in January (season1), June (season 6) and December (season 12). There is a significant dependency on season and time of day. On the basis of the provided measurement data, the dependency of demand on weekdays is not relevant. An explanation of daily differences with stochastic noise patterns and uncertainty of the electricity system is plausible. An analysis is given in the next table.

The given demand measurement data is shown in dependency of days (rows) and daytimes (columns). Regular color patterns indicate systematic dependencies on calendar cycles. Color patterns with slight differences indicate stochastic noise. Other patterns, especially for fields with abnormally high and irregular color differences from neighboring fields indicate singular events, like failures.

Nr	Year	Montl	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
270	2011	8	25/8/11	131	143	167	148	126	124	151	177	181	179	181	179	179	181	187	189	210	70	202
271	2011	8	26/8/11	126	137	168	139	117	121	151	168	174	167	172	177	174	170	170	190	200	213	204
272	2011	8	27/8/11	128	137	162	134	117	135	155	165	179	183	176	172	175	173	173	191	213	215	200
273	2011	8	28/8/11	123	136	152	138	119	126	154	176	185	185	178	176	176	172	179	179	200	202	195
274	2011	8	29/8/11	113	139	149	119	113	130	152	170	177	167	175	173	165	159	170	161	210	197	186
275	2011	8	30/8/11	122	104	106	111	139	191	159	225	208	197	193	176	161	151	77	127	132	138	177
276	2011	8	31/8/11	91	89	88	96	116	168	190	190	171	162	157	149	143	137	135	131	131	143	189
281	2011	9	1/9/11	88	86	81	88	96	149	158	120	135	120	81	103	97	92	87	80	87	117	164
282	2011	9	2/9/11	72	70	72	74	85	122	147	151	148	153	151	151	137	133	139	127	131	145	189
283	2011	9	3/9/11	79	75	77	74	96	153	181	169	175	172	172	167	159	152	149	150	154	168	61
284	2011	9	4/9/11	80	76	80	87	101	141	158	183	175	176	183	178	175	156	157	153	160	171	199
285	2011	9	5/9/11	85	83	82	85	102	162	160	161	172	178	188	184	52	142	142	171	169	179	197
286	2011	9	6/9/11	93	91	90	94	121	171	179	181	187	187	194	186	173	173	172	172	173	185	28
287	2011	9	7/9/11	90	88	88	93	116	162	184	190	183	184	191	181	170	173	173	172	163	176	214
288	2011	9	8/9/11	96	91	93	97	113	162	187	176	179	175	170	171	167	179	173	173	171	183	209
289	2011	9	9/9/11	100	93	91	94	95	154	184	180	174	183	183	183	164	164	165	150	153	165	212
290	2011	9	10/9/11	91	89	88	92	107	170	190	192	160	168	177	184	168	166	167	176	175	195	213
291	2011	9	11/9/11	96	94	94	97	112	176	193	192	189	189	185	182	170	164	163	178	169	183	210
292	2011	9	12/9/11	95	94	91	101	111	171	195	193	184	180	186	179	174	166	164	172	174	218	225
293	2011	9	13/9/11	99	94	94	100	116	174	196	189	195	195	110	129	130	128	147	147	166	175	198
294	2011	9	14/9/11	89	86	82	83	95	161	183	173	160	170	175	172	168	163	166	160	175	204	189
295	2011	9	15/9/11	88	85	84	84	104	165	199	176	176	188	179	184	175	174	173	172	193	196	203
296	2011	9	16/9/11	86	79	79	73	89	134	171	171	165	176	172	170	150	144	141	130	146	180	199
297	2011	9	17/9/11	78	74	74	79	108	175	187	180	178	177	186	161	155	155	161	157	156	182	197
298	2011	9	18/9/11	80	74	73	78	102	168	164	169	40	177	173	174	156	154	154	154	168	194	35
299	2011	9	19/9/11	75	77	77	78	99	172	181	181	179	180	179	174	161	161	156	154	135	177	190
300	2011	9	20/9/11	79	75	75	81	95	176	184	173	170	38	149	141	126	133	127	127	129	199	217
301	2011	9	21/9/11	81	77	76	85	105	165	184	190	181	181	182	182	156	157	156	160	167	190	210
302	2011	9	22/9/11	75	75	75	86	97	151	182	172	168	166	168	171	156	149	169	169	167	189	212
303	2011	9	23/9/11	80	72	72	72	92	144	177	171	170	178	169	166	154	149	149	145	149	186	202
304	2011	9	24/9/11	72	72	71	77	96	153	190	177	177	178	177	176	152	147	152	154	153	199	214
305	2011	9	25/9/11	75	74	74	78	103	170	197	182	180	179	177	175	156	146	153	159	165	204	206
306	2011	9	26/9/11	76	74	74	81	99	176	188	173	46	36	36	37	20	155	169	131	183	210	210
307	2011	9	27/9/11	78	73	73	77	111	176	197	190	198	186	190	184	174	173	165	164	178	216	224
308	2011	9	28/9/11	76	71	70	75	114	168	194	184	178	179	181	172	160	158	157	158	172	204	230
309	2011	9	29/9/11	73	68	68	77	107	170	197	188	184	177	188	173	158	159	157	165	168	207	216
310	2011	9	30/9/11	76	73	75	82	100	153	181	182	180	180	164	177	158	151	140	142	158	205	214

Figure 10.2.2-3: Visualization of pattern structures for demand measurement data around Kabul 2011

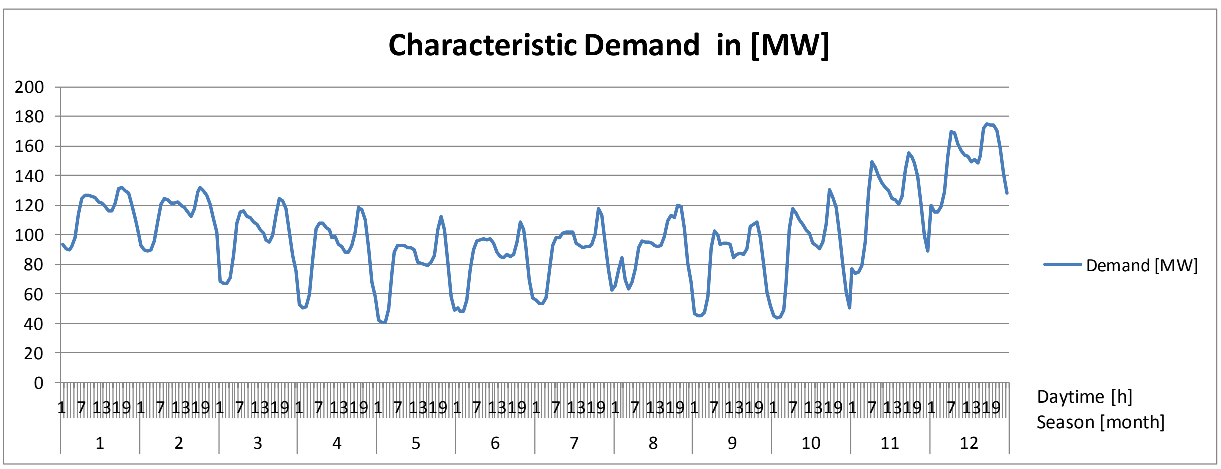


Figure 10.2.2-4: Characteristic demand in [MW]

Due to the minor influence of weekdays on the demand characteristic, we derived a demand curve for dependency on seasons for the months from 1 to 12 and time of day for the hours from1 to 24. As a result of the above analysis, we use a standardized representation in the model with 12 months per year, 1 day per month and 24 hours per day. The above graph was derived from measurement data for Kabul in 2011 and validated with measurement data in 2010. The figures are normalized to an average power of 100 MW. During the year the demand increases in 2011 and a comparable increase can be seen in 2010. From estimated demand projections, we expect a similar rise during the planning period.

The next graph gives an example for the derived demand data for the optimization model. It shows the demand curves for the base case during 2032. For the optimizations, we derived demand curves per demand case, grid segment and year.

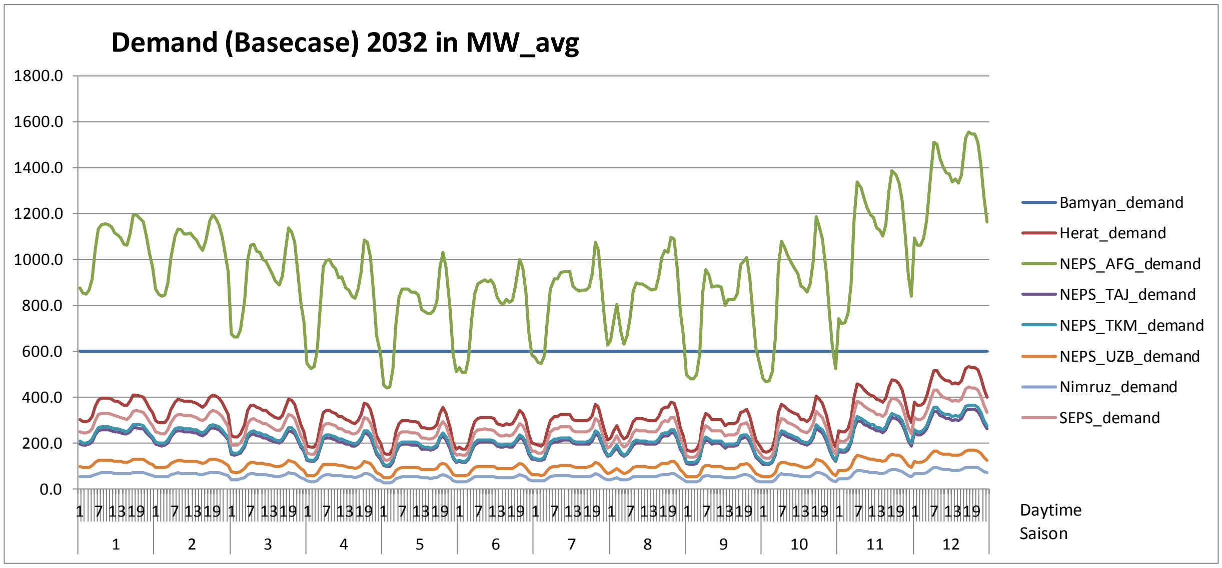


Figure 10.2.2-5: Derived demand curves in 2032 for the base case

10.2.3 Hydro power plants (HPP)

HPP	Grid_Segment	Capacity	Storage	OPEX	Decision	General_ Availability
Unit		[MW]		[USD/MWh]		[a]
Salma _HPP	Herat	40.0	RoR	10.15	candidate	*
Baghdara_HPP	NEPS_AFG	210.0	day	6.82	candidate	*
Surobi_HPP	NEPS_AFG	180.0	day	7.86	candidate	*
Kunar_A_HPP	NEPS_AFG	789.0	day	4.61	candidate	*
Gulbahar_HPP	NEPS_AFG	120.0	day	9.26	candidate	*
Kama_HPP	NEPS_AFG	45.0	RoR	8.88	candidate	*
Kunar_B_HPP	NEPS_AFG	300.0	day	4.44	candidate	*
Kukcha_HPP	NEPS_TAJ	445.0	RoR	6.88	candidate	*
Kilagai_HPP	NEPS_TAJ	60.0	RoR	9.26	candidate	*
Kajaki_Extension_HPP	SEPS	18.5	day	9.89	candidate	*
Kajaki_Addition_HPP	SEPS	100.0	day	6.09	candidate	*
Olambagh_HPP	SEPS	90.0	RoR	9.91	candidate	*
Naghlu_HPP	NEPS_AFG	100.0	day	10.00	fixed	2011 - 2032
Sarobi_HPP	NEPS_AFG	22.0	day	10.00	fixed	2011 - 2032
Mahipar_HPP	NEPS_AFG	66.0	day	10.00	fixed	2011 - 2032
Darunta_HPP	NEPS_AFG	11.5	day	10.00	fixed	2011 - 2032
Kajaki_2011_HPP	SEPS	33.0	day	10.00	fixed	2011 - 2032
Grishk_HPP	SEPS	2.4	RoR	10.00	fixed	2011 - 2032
Pul_i_Chumri_HPP	NEPS_UZB	8.2	RoR	10.00	fixed	2011 - 2032
* Candidate						

Table 10.2.3-1: Existing and projected HPPs

The table above shows existing and projected hydro power plants with the associated grid segment stated for each. The table states the nominal (equivalent to maximum power) capacity, with seasonal dependency given below. Due to differing characteristic of HPP generation and demand, the HPP controllability exerts a great influence on overall system design. Due to the minor demand dependency on weekdays, we restrict our discussion to annual and daily storage behavior. Based on the provided information, we must assume that none of the HPPs may be used as controllable annual energy storage. We can classify HPPs into two categories:

- run-of-river (**RoR**) plants have constant electricity generation throughout one season
- HPPs with **day storage** may vary electricity generation during one day as long as the daily average does not exceed the seasonal load and subject to a constant minimum ecological flow of 7% of the nominal capacity.

Based on data provided for annual costs for HPPs, we estimated the specific OPEX per MWh. An HPP's OPEX influences its dispatching order in relation to other HPPs, and may influence capacity expansion decisions. There is no influence on the dispatching order in conjunction with thermal power plants or electricity imports, due to HPP dispatching opportunity costs being significantly lower.

For simplicity, for the capacity expansion planning model, we assumed that rehabilitation for all existing HPP is completed at the beginning of 2012. There are no impacts on capacity expansion decisions due to the first decisions being taken after all rehabilitation is finished.

HPP_Load in [%]	**Season**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Baghdara_HPP	33	35	36	74	100	100	100	48	26	24	21	33
Darunta_HPP	22	24	55	100	100	100	100	60	35	30	26	24
Grishk_HPP	24	55	100	100	100	100	60	35	30	26	24	22
Gulbahar_HPP	22	24	55	100	100	100	100	60	35	30	26	24
Kajaki_2011_HPP	24	55	100	100	100	100	60	35	30	26	24	22
Kajaki_Addition_HPP	24	55	100	100	100	100	60	35	30	26	24	22
Kajaki_Extension_HPP	24	55	100	100	100	100	60	35	30	26	24	22
Kama_HPP	22	24	55	100	100	100	100	60	35	30	26	24
Kilagai_HPP	24	22	24	55	100	100	100	100	60	35	30	26
Kukcha_HPP	24	22	24	55	100	100	100	100	60	35	30	36
Kunar_A_HPP	22	24	55	100	100	100	100	100	100	60	35	30
Kunar_B_HPP	22	24	55	100	100	100	100	60	35	30	26	24
Mahipar_HPP	22	24	55	100	100	100	100	60	35	30	26	24
Naghlu_HPP	22	24	55	100	100	100	100	60	35	30	26	24
Olambagh_HPP	24	55	100	100	100	100	60	35	30	26	24	22
Pul_i_Chumri_HPP	22	24	55	100	100	100	100	60	35	30	26	24
Salma_HPP	24	55	100	100	100	100	60	35	30	26	24	22
Sarobi_HPP	22	24	55	100	100	100	100	60	35	30	26	24
Surobi_HPP	22	24	55	100	100	100	100	60	35	30	26	24

Table 10.2.3-2: Seasonally dependent HPP load curves

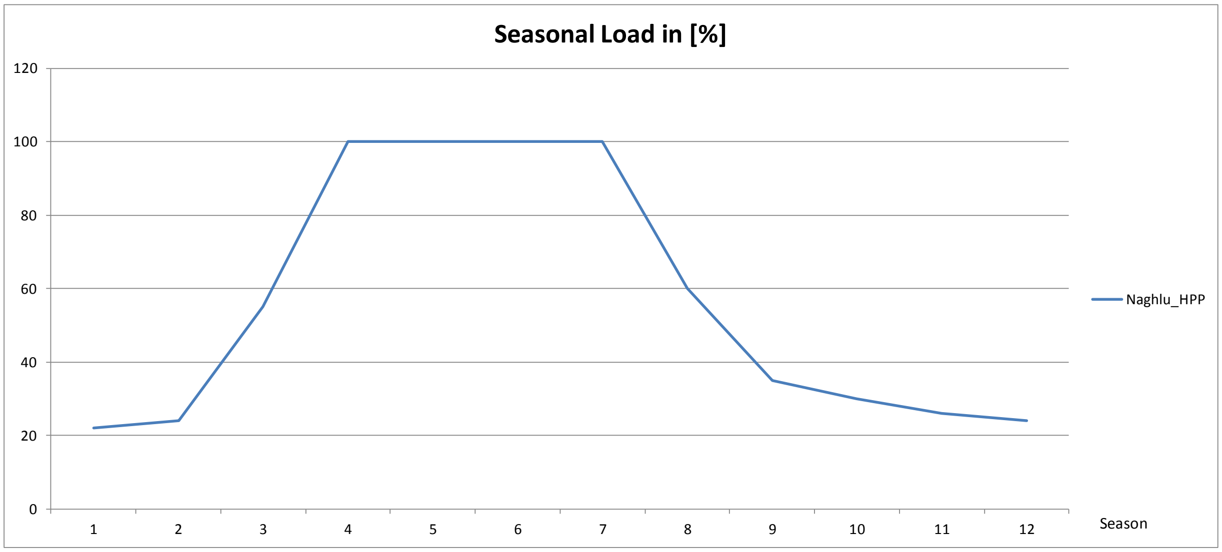


Figure 10.2.3-1: Example of seasonal load in [%]

The above table gives the load characteristic of all HPPs in [%] of nominal capacity depending on the season (month). The corresponding graph shows Naghlu HPP as an example.

All hydropower plants have their seasonal peak (100% load) in summer and a minimum load of about 22 % in winter. The minimum HPP load in winter coincides with the annual demand maximum.

Due to the high impact of seasonal dependency of hydro load curves on overall system behavior and no relevant weekday dependencies we applied a time model with 12 seasons (equivalent to months) and one day per season.

10.2.4 Thermal power plants (TPP)

TPP	Grid_Segment	Capacity	Fuel	Efficiency	Operating_Hour	OPEX	Decision	General_ Availability
Unit		[MW]		[1]	[h/a]	USD/MWh		[a]
Sheberghan_TPP	NEPS_TKM	400.0	Natural_Gas	0.45	8000	9.5	candidate	*
Bamyan_TPP	NEPS_AFG	1200.0	Coal	0.325	6000	25.5	candidate	*
Balkh_TPP	NEPS_UZB	48.0	Diesel	0.33	8000	17.0	fixed	2011 -2032
Tarakhil_TPP	NEPS_AFG	105.0	Diesel	0.39	8000	9.0	fixed	2011 -2032
Kabul_GT34_TPP	NEPS_AFG	44.8	Diesel	0.24	8000	9.0	fixed	2011 -2032
Nangarhar_TPP	NEPS_AFG	2.7	Diesel	0.39	8000	9.0	fixed	2011 -2032
SEPS_TPP	SEPS	56.5	Diesel	0.39	8000	9.0	fixed	2011 -2032
* Candidate								

Table 10.2.4-1: Thermal power plants

The above table summarizes the characteristics of thermal power plants. For the Sheberghan site, we choose the more efficient gas power plant solution, mainly because of general efficiency aspects and limited deposits. In conjunction with less efficient electricity generation, the limited deposits will lead to higher coal-based electricity generation or additional import requirements. Both have significantly higher costs than gas-based electricity generation and evidently not optimal.

For annual operating hours and efficiency, we use linear model constraints. Due to a hydro generation surplus in summer, additional constraints to ensure consistent major inspection and maintenance outage periods for thermal power plants are not required.

OPEX per MWh is derived from constant annual costs and operation-dependent costs. TPP OPEX influences the dispatching order between thermal based electricity generation and thermal based electricity imports. There is a very low sensitivity in conjunction with HPP dispatching. There is a high sensitivity for coal-fired power plants for dispatching in conjunction with thermal based electricity imports. There no sensitivity to capacity expansion, since decisions for coal-fired power plants will be taken independently of power expansion planning in line with mine development.

We assume that all existing thermal power plants may be used as reserve and for peak generation throughout the planning period.

To simplify data management, reports and graphs, we aggregated some of the power plants. Due to identical parameters and identical grid segmentation, model and results are identical.

TPP	Grid segment	Capacity	Additional demand	First year
		[MW]	[MW]	
Bamyan (copper mine)		400.0	200	2027
Haji Gag (ore mine)		800.0	400	2029
Bamyan TPP	**NEPS AFG**	**1200.0**	**600**	**capacity constraint**

Table 10.2.4-2: Aggregation of coal power plants

The above table shows the aggregation of coal power plants. Based on the provided information we assumed two coal-fired power plants. The first with a capacity of 400 MWe starts operation in 2027 simultaneously with the development of a copper mine and an additional demand of 200 MW. The second starts operation in 2029 with a capacity of 800 MWe simultaneously with the development of an ore mine in Haji Gag with an additional demand of 400 MW. We assumed an annual operating time of 6000 h/a for the power plant and an annual operating time of 8760 h/a for the demand. For the capacity expansion model, we use the term **Bamyan TPP** for the aggregated coal power plants.

TPP	Grid segment	TPP Capacity
		[MW]
NW Kabul GT 3		21.8
NW Kabul GT 4		23.0
Kabul_GT34_TPP	**NEPS AFG**	**44.8**

Table 10.2.4-3: Aggregation of Kabul gas turbines

The table above shows the two Kabul gas turbines. In the capacity expansion model we use the term Kabul_GT34_TPP for aggregation of the two power plants.

The table below shows the diesel based thermal power plants in the SEPS subsystem. In the capacity expansion model we use the term **SEPS TPP** for the aggregated diesel-based power plants in the SEPS subsystem.

TPP	Grid segment	Capacity
		[MW]
Kandahar KTA50	SEPS	11.9
Kandahar KTA50, exp	SEPS	12.0
Kandahar QSK 60	SEPS	8.8
Kandahar USACE	SEPS	20.0
Lashkar Gah / Helmand	SEPS	3.8
SEPS TPP	**SEPS**	**56.5**

Table 10.2.4-4: Aggregation of SEPS thermal power plants

10.2.5 Resources

Resource	Type	Energy price	CO2_Emission	Price escalation	General availability	Constraint
		[USD/MWh]	[kg/MWh_fuel]		[a]	
Natural gas	Fuel	10.4	230	1.00	2011 -2032	via TPP
Coal	Fuel	20.13	390	1.00	2011 -2032	via TPP
Diesel	Fuel	100	350	1.00	2011 -2032	via TPP

Table 10.2.5-1: Fuel resources

The above table summarizes the fuel data for the thermal power plants. A detailed discussion is given in the chapters above. The additional preliminary analysis below is based on the given general discount rate of 12% for the base variant with alternative scenario variants with general discount rates of 9% and 15%.

Natural gas and coal are domestic resources. Due to the existing infrastructure and baseline conditions in Afghanistan, we assumed a restricted market access. For our calculations, we assumed production costs without specific price escalations. Coal is based on domestic resources, with the projects including development of coal mines in conjunction with development of copper and ore mines. Because of the high discount rates, restricted market access and large differences between fuel prices, valuation of the residual deposits is of minor influence.

At present, diesel is expensive due to security and infrastructure aspects. There is a high uncertainty regarding developments even in the near future. In the context of the overall system, the price for diesel will hinder diesel-based generation if there are other options. An exception is diesel-based electricity generation by existing power plants for rare peak situations. For the model, we assume that baseline conditions for security and infrastructure will change and compensate for price escalations in international markets.

The given prices are assumed for large diesel engines around Kabul and Kandahar. Prices for decentralized systems in other regions are higher and discussed in conjunction with decentralized renewable systems.

The underlying fuel prices vary greatly and we expect a minor influence of small fuel price changes, escalation factors and valuation of deposits. Sensitivity is low according to the clear internal (price) ranking of these resources. Changes may result when compared with external resources, for example gas-based electricity generation in TKM and UZB.

We estimate emissions (GHG – greenhouse gas) with CO_2 equivalents. There are various estimates of specific emissions of electricity, which vary dependent on assumed losses, transport conditions and extraction technologies. Other influences are given by differing assumptions for the construction of power plants and different load factors. We use data from German investigations [Krewitt1997], [Wagner2007] and we have derived specific emission coefficients for fuels. For electricity imports from TKM and Iran, we assumed emissions comparable to the gas power plants in Sheberghan.

Emissions are stated for information purposes. Due to the provided information we do not include prices for emissions in the objective function and there is no dependency of the calculated decisions on the assumed emission factors. For hydro power plants and for (hydro based) imports from TAJ, we do not calculate specific emission factors in the model.

10.2.6 Electricity import / export

Import	Source	Grid_Segment	Capacity	Tarif	Price_ Escalation	Decision	General Availability
			[MW]	[USD/MWh]	[1/a]		[a]
TKM_2_Herat_import	TKM	Herat	45	28	1.00	fixed	2011 - 2019
TKM_2_NEPS_TKM_import	TKM	NEPS_TKM	40	28	1.00	fixed	2011 - 2017
TKM_2_NEPS_UZB_import	TKM	NEPS_UZB	500	55	1.00	candidate	*
TKM_2_NEPS_UZB_add_import	TKM	NEPS_UZB	500	55	1.00	candidate	*
UZB_2_NEPS_UZB_import	UZB	NEPS_UZB	300	60	1.00	fixed	2011 - 2032
TAJ_2_NEPS_TAJ_import	TAJ	NEPS_TAJ	300	35	1.00	fixed	2011 - 2032
IRAN_2_Herat_import	Iran	Herat	83	30	1.00	fixed	2011 -2019
IRAN_2_Nimruz_import	Iran	Nimruz	70	30	1.00	fixed	2011- 2026
* Candidate							

Table 10.2.6-1: Import options

The table above gives an overview of import options. The import options summarize aspects of commercial contracts and power lines. Detailed discussions of tariffs and options for grid expansion are given in the relevant chapters. The general availability is in general defined by grid restrictions. Additional capacity restrictions are given in a separate chapter below.

The import from TAJ is based on hydro generation. Due to the given information we assumed a load curve with 100% load in summer (April to September) and 0% load in winter. For simplicity, we do not take into account that at present isolated grid segments in Afghanistan are served the whole year round by TAJ imports in the first periods. Imports from UZB and TKM are TPP-based and may serve firm energy. Despite the stated figure of 325 MW capacity, we restricted the import to 300 MW. This restriction does not take effect in initial years. In later years, there is a high generation surplus in summer and this does not affect capacity expansion, but may have slight effects on dispatching order.

For imports from UZB and TAJ, we assumed a constant import capacity of 300 MW each throughout the planning period. Beginning in 2020, the import capacity from UZB is required during the winter, with imports from TAJ is restricted to summer. The given baseline conditions indicate that both import lines may share one HVDC hub.

There is high uncertainty regarding future import tariffs. In our expectation, long term contracts and a system design that minimizes dependencies from others is a universal objective, irrespective of detailed optimization results and may be discussed together with the results of the optimizations. Despite the high dependency of Afghanistan on imports, there is a low sensitivity to the import prices of electrical energy. The reason is, that – assuming the given projections will apply – especially for winter / peak electricity there are fewer choices and in the long run Afghanistan will use all analyzed options.

The exception is electricity generation in summer. But expansion of HPP capacity is restricted by the decreasing load factors due to the required peak load in winter.

On the basis of the given information, we do not take the export options to PAK and TAJ in the scenario model into account.

10.2.7 Grid connections

The network configuration is analyzed in the relevant chapters above with the results summarized in the table below. There is a baseline – fixed – configuration of required grid connections according to the given baseline conditions. Optional grid connection candidates are part of the optimization model. Dedicated import lines are described together with the import options. For simplification, losses are factored into the demand and losses for grid connections are not regarded separately. A detailed calculation and validation of load flows is given separately in the relevant chapter.

Grid_Connection	Grid_Seg_1	Grid_Seg_2	Capacity	Decision	General_ Availability
Unit			[MW]		[a]
Salang_conn	NEPS_UZB	NEPS_AFG	1450	fixed	2011 - 2032
NEPS_2_SEPS_conn	NEPS_AFG	SEPS	300	candidate	*
NEPS_UZB_2_NEPS_TKM_conn	NEPS_UZB	NEPS_TKM	**	fixed	2020 - 2032
NEPS_UZB_2_NEPS_TAJ_conn	NEPS_UZB	NEPS_TAJ	**	fixed	2020 - 2032
NEPS_2_Herat_conn	NEPS_TKM	Herat	500	fixed	2020 - 2032
SEPS_2_Nimruz_conn	SEPS	Nimruz	100	fixed	2027 - 2032
* Candidate					
** unestricted					

Table 10.2.7-1: Main grid connections (without imports)

10.2.8 Additional capacity restrictions

The table below shows additional capacity restrictions of import options, grid connections and coal power plants (Bamyan TPP el).

Asset	From period	To period	Capacity
	[a]	[a]	[MW]
TKM_2_NEPS UZB_import	2018	2019	300
IRAN_2_Nimruz_import	2012	2014	20
Salang conn	2012	2014	300
Salang conn	2015	2017	450
Bamyan TPP el	2027	2028	400
Bamyan TPP el	2029	2032	1200

Table 10.2.8-1: Additional capacity restrictions

10.2.9 Capacity expansion candidates

The table below summarizes all capacity expansion candidates that require specific decisions, which are graded according to their complexity:

- binary decision – build total capacity: yes or no; optimize optimal period for total capacity
- per unit – build decision and build period are optimized per unit; unit size is separated
- fixed decision – decision has been taken; take into account or optimize capacity expansion parameters.

The table may not include linear capacity expansion of grid connections or decisions that are fixed during the preliminary analysis. On the basis of the provided information and the preliminary analysis we applied the given values for useful life and we do apply price escalations (price escalation = 1.0).

Candidate	First_ Period	Useful_ Life	CAPEX	Price_ Escalation	Decision	Unit_ Size
	[a]	[a]	[USD/kW]	[1/a]		[MW]
TKM_2_NEPS_UZB_import	2018	50	424	1.00	fixed	
TKM_2_NEPS_UZB_add_import	2020	50	424	1.00	binary	
NEPS_2_SEPS_conn	2016	50	667	1.00	per_unit	150
Bamyan_TPP_el	2027	25	1700	1.00	fixed	
Sheberghan_TPP_el	2017	25	1700	1.00	per_unit	50
Kunar_B_HPP	2022	50	2200	1.00	binary	
Kunar_A_HPP	2023	50	2788	1.00	binary	
Kajaki_Addition_HPP	2022	50	3000	1.00	binary	
Baghdara_HPP	2022	50	3143	1.00	binary	
Kukcha_HPP	2023	50	3461	1.00	binary	
Surobi_HPP	2022	50	3889	1.00	binary	
Kama_HPP	2022	50	4400	1.00	binary	
Gulbahar_HPP	2022	50	4583	1.00	binary	
Kilagai_HPP	2022	50	4583	1.00	binary	
Olambagh_HPP	2022	50	4889	1.00	binary	
Salma _HPP	2012	50	5000	1.00	fixed	
Kajaki_Extension_HPP	2012	50	4865	1.00	fixed	

Table 10.2.9-1: Candidates for capacity expansion planning

To simplify model implementation, the import option from TKM to NEPS UZB is divided into a fixed part of 300 MW to 500 MW from 2018 to 2020 and an optional part of 500 MW starting in 2020 at the earliest.

10.2.10 Summary of preliminary analysis, scenarios

The projected **demand** greatly influences capacity expansion planning. Also having a major influence is the **discount rate**. On one hand, a high discount rate reflects the high uncertainty and high capital costs. On the other, desired investments in capital-intensive technologies may be prevented by high discount rates.

As a result of the preliminary analysis, several decisions for capacity expansion planning are fixed. In particular, several grid connections are required to satisfy the projected demand. The expansion model concentrates on aspects that influence the capacity expansion plan. Due to the given baseline conditions, there is a relative low impact of **escalation factors** for fuel prices and electricity import tariffs on capacity decisions.

The influence of the **TAPI** gas pipeline can be limited. The electrical generation costs are equal to or higher than the given sites in TKM and Sheberghan. Taking into account the given baseline conditions we expect comparable or even higher costs for transportation of gas from TKM in comparison with transport of electricity. Gas-based electricity generation in the SEPS region may be prevented by restrictions of the NEPS-SEPS grid connection. Depending on the road map, TAPI-based electricity generation may substitute coal-based electricity generation or supplement the existing system. In particular, additional electricity generation in the SEPS region counters unserved demand due to grid constraints.

The high potential of HPP results in high generation potentials in summer and high capacity requirements during winter evenings. As a result of the preliminary analysis, the system is dominated by HPP characteristics, load characteristics and the required additional firm capacity.

In consequence, electricity generation based on PV and wind has only a minor influence on the overall grid-based electricity system. From the given information, **PV- and wind-based electricity generation** competes with hydro-based generation, especially RoR HPP. Because of the given baseline conditions, we expect only a minor influence of PV- and wind-based electricity generation on the overall grid-based electricity system, but market niches may exist. This is discussed in a separate chapter in connection with decentralized off-grid systems.

There are additional load flow calculations. Simplifications of the capacity planning model according to OPEX estimates are not relevant for capacity expansion planning, but may affect dispatching of generation assets. In particular, relatively high sensitivities for **dispatching coal-fired power plants** versus thermal based electricity imports may lead to modified dispatching and modified load characteristics for Afghan power plants. Due to very great uncertainties at present and lengthy validation and decision processes, we do not anticipate additional findings for calculating additional variants with different parameters for various dispatching configurations for coal-fired power plants versus import options.

Loads of domestic and external power plants used for import to Afghanistan will be reduced significantly by higher shares of HPP-based electricity generation. From the given information we assumed **constant import tariffs** and do not include constraints to ensure a high load for these electricity imports. An important issue is validation of long-term dependencies of import tariffs on load factors. On the basis of the given uncertainties and available information, at present we are not anticipating additional findings. We propose, though, that this issue be discussed in future in a regional context, especially regarding export options to PAK. An indicator may be given by the load of gas-fired power plants in Sheberghan.

The table below gives an overview of the resulting scenario tableau for the optimizations. The tableau includes the base variant (base case demand, 12% discount rate) and variations of the demand and the discount rate.

Scenario tableau	**Demand**			
Discount rate		**1.09**	**1.12**	**1.15**
	low case	low_dr109	low_dr112	low_dr115
	base case	base_dr109	**base_dr112***	base_dr115
	high case	high_dr109	high_dr112	high_dr115

*** Base case**

Table 10.2.10-1: Scenario tableau

10.3 Results – Least Cost Planning

This subchapter presents the results of the optimizations. It starts with a detailed description of the base variant. For other variants we describe common results and differences in relation to the base variant. The detailed input data and detailed results are given in electronic form for further analysis.

10.3.1 Base case, 12% discount rate

This variant is based on the demand base case and a discount rate of 12%.

10.3.1.1 Capacity expansion plan

The table below shows the capacity expansion plan for all candidates.

	NEPS_2_SEPS_conn	Sheberghan_TPP_el	TKM_2_NEPS_UZB_import	TKM_2_NEPS_UZB_add_import	Kunar_B_HPP	Kunar_A_HPP	Bamyan_TPP_el	Kajaki_Addition_HPP	Olambagh_HPP	Baghdara_HPP	Gulbahar_HPP	Kama_HPP	Kilagai_HPP	Kukcha_HPP	Surobi_HPP
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	150	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	150	150	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	150	200	300	0	0	0	0	0	0	0	0	0	0	0	0
2019	150	200	300	0	0	0	0	0	0	0	0	0	0	0	0
2020	150	200	500	500	0	0	0	0	0	0	0	0	0	0	0
2021	150	250	500	500	0	0	0	0	0	0	0	0	0	0	0
2022	150	350	500	500	0	0	0	0	0	0	0	0	0	0	0
2023	300	400	500	500	0	0	0	0	0	0	0	0	0	0	0
2024	300	400	500	500	300	0	0	0	0	0	0	0	0	0	0
2025	300	400	500	500	300	0	0	0	0	0	0	0	0	0	0
2026	300	400	500	500	300	789	0	0	0	0	0	0	0	0	0
2027	300	400	500	500	300	789	400	0	0	0	0	0	0	0	0
2028	300	400	500	500	300	789	400	100	0	0	0	0	0	0	0
2029	300	400	500	500	300	789	1200	100	90	0	0	0	0	0	0
2030	300	400	500	500	300	789	1200	100	90	0	0	0	0	0	0
2031	300	400	500	500	300	789	1200	100	90	0	0	0	0	0	0
2032	300	400	500	500	300	789	1200	100	90	210	0	0	0	0	0

Table 10.3.1-1: Base case + 12% discount rate – capacity expansion in [MW]

The **grid connection** from NEPS to SEPS starts operation with a capacity of 150 MW in 2016. Expansion to 300 MW is required from 2023.

Optional expansion candidates for **thermal generation** include gas power plants in Sheberghan and import options from TKM. The maximum import from TKM is to be realized as soon as possible. Maximum generation at Sheberghan is to be realized by 2023. The decision depends on the unit size of the additional power import line from TKM. Otherwise the expansion order of Sheberghan and TKM import may change. There are no additional thermal generation options included in the system. The decision on the coal-fired power plant (Bamyan TPP) is taken externally depending on the development of the copper and ore mines.

Separate investigations show that earlier construction of coal-fired power plants without the mines is not economic, even if possible.

Additional production from **HPP based generation** starts in 2024 with the production start of Kunar B (300 MW). In the following years Kunar A (789 MW), Kajaki_Addition (100 MW), Olambagh and Baghdara are included. Decisions on Kunar B and Kunar A are cost-based, with the order of implementation of these two HPP may depend on unit size. The decision on Kajaki_Addition is cost based too. The decision on Olambagh is influenced by the restricted generation potential in SEPS and the grid connection to Nimruz in conjunction with grid constraints (NEPS 2_SEPS_conn). The decision on Baghdara is motivated by costs. The summer potential of imports from TAJ and the unit size hinders additional HPP capacity, for example Kukcha. The graph below shows the capacity expansion.

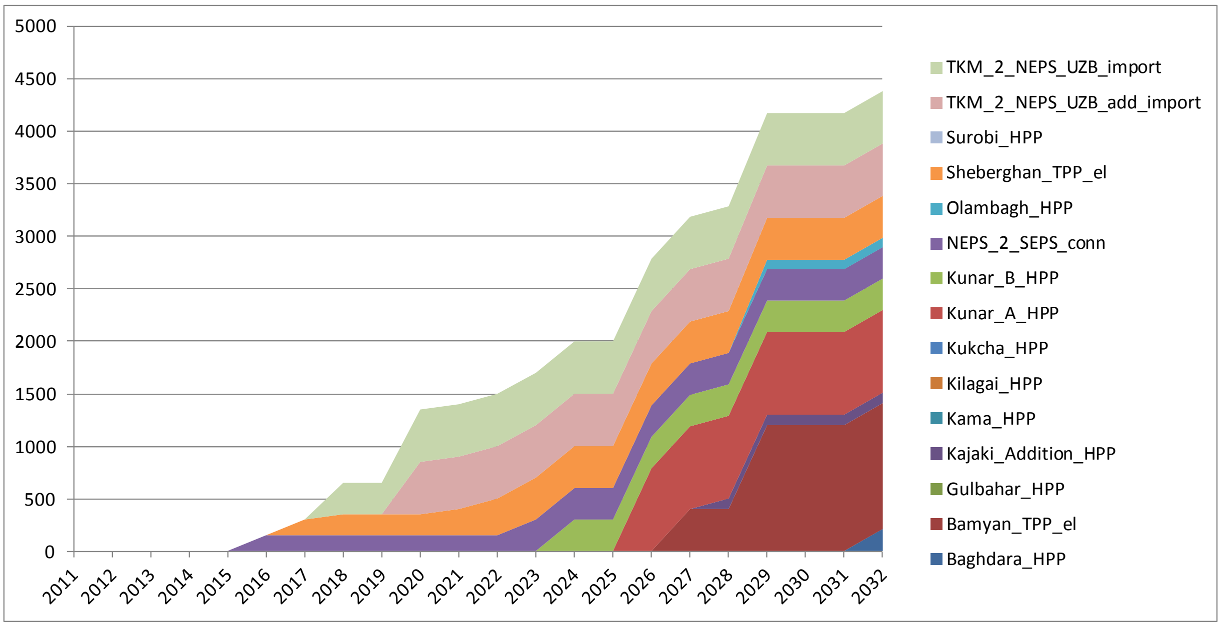


Figure 10.3.1-1: base case + 12% discount rate - Capacity expansion in [MW]

10.3.1.2 Costs of the projects

The table below shows CAPEX and their annual distribution for the expansion plan. The table includes the annual CAPEX as shown in the graph and the corresponding net present values (NPV) of the corresponding investments.

Period	Invest	Discount_ factor	NPV
	[mioUSD]	[1]	[mioUSD]
2012	0	1.000	0
2013	0	0.893	0
2014		0.797	80
2015	0	0.712	0
2016	100	0.636	63.6
2017	255	0.567	145
2018	212	0.507	108
2019	0	0.452	0
2020	297	0.404	120
2021	85	0.361	31
2022	170	0.322	55
2023	185	0.287	53
2024	660	0.257	169
2025	0	0.229	0
2026	2200	0.205	450
2027	680	0.183	124
2028	300	0.163	49
2029	1800	0.146	262
2030	0	0.130	0
2031	0	0.116	0
2032	660	0.104	68
Sum	**7604**		**1700**

Table 10.3.1-2: Base case + 12% discount rate – costs for capacity expansion in [million USD]

10.3.1.3 Annual Energy

	Baghdara_HPP	Balkh_TPP_el	Bamyan_TPP_el	Darunta_HPP	Grishk_HPP	Kabul_GT34_TPP_el	Kajaki_2011_HPP	Kajaki_Addition_HPP	Kajaki_Extension_HPP	Kunar_A_HPP	Kunar_B_HPP	Mahipar_HPP	Naghlu_HPP	Nangarhar_TPP_el	Olambagh_HPP
2012	0	346	0	48	5	0	139	0	37	0	0	284	487	0	0
2013	0	372	0	49	8	4	151	0	45	0	0	290	492	1	0
2014	0	384	0	50	10	24	156	0	57	0	0	298	494	2	0
2015	0	384	0	51	11	30	159	0	72	0	0	311	495	3	0
2016	0	384	0	53	11	39	163	0	83	0	0	314	495	3	0
2017	0	384	0	55	11	78	163	0	86	0	0	322	495	6	0
2018	0	384	0	56	12	1	163	0	89	0	0	325	495	1	0
2019	0	384	0	57	12	24	163	0	90	0	0	327	495	1	0
2020	0	384	0	57	12	0	163	0	91	0	0	327	495	0	0
2021	0	384	0	57	12	0	163	0	91	0	0	327	495	0	0
2022	0	319	0	57	12	0	163	0	91	0	1485	327	495	0	0
2023	0	382	0	57	12	2	163	0	91	0	1485	327	495	1	0
2024	0	210	0	46	10	0	146	0	76	4674	1485	271	431	0	0
2025	0	210	0	49	10	0	147	0	80	4704	1485	281	435	0	0
2026	0	210	0	48	10	15	147	449	78	4727	1485	279	435	2	0
2027	0	210	247	50	10	0	148	461	82	4754	1485	285	445	0	0
2028	0	212	359	50	10	0	152	470	82	4763	1485	294	449	0	0
2029	0	330	1710	57	12	0	163	493	91	4772	1485	327	495	0	437
2030	0	351	2054	57	12	0	163	493	91	4772	1485	327	495	0	442
2031	0	384	2367	57	12	0	163	493	91	4772	1485	327	495	0	444
2032	968	355	2535	56	12	13	163	493	89	4772	1485	326	495	2	435

	Pul_i_Chumri_HPP	Salma_HPP	Sarobi_HPP	SEPS_TPP_el	Sheberghan_TPP_el	Surobi_HPP	Tarakhil_TPP_el	TAJ_2_NEPS_TAJ_import	UZB_2_NEPS_UZB_import	TKM_2_NEPS_TKM_import	TKM_2_NEPS_UZB_add_import	TKM_2_NEPS_UZB_import	TKM_2_Herat_import	IRAN_2_Herat_import	IRAN_2_Nimruz_import
2012	33	197	98	87	0	0	36	97	983	198	0	0	389	306	112
2013	35	197	103	125	0	0	68	118	1185	234	0	0	391	352	119
2014	35	197	107	173	0	0	116	141	1394	270	0	0	392	400	127
2015	36	197	108	225	0	0	195	168	1607	300	0	0	394	452	141
2016	37	197	108	112	0	0	242	200	1752	349	0	0	394	505	155
2017	38	197	109	148	489	0	316	236	2017	350	0	0	394	556	171
2018	39	197	109	35	899	0	63	266	809	0	0	2174	394	598	188
2019	40	197	109	63	959	0	76	298	1005	0	0	2303	394	631	207
2020	41	197	109	12	2800	0	0	1318	188	0	1643	2776	0	0	228
2021	41	197	109	22	3200	0	5	1318	206	0	1873	2650	0	0	241
2022	41	197	109	33	3200	0	4	1238	212	0	1500	2351	0	0	259
2023	41	197	109	31	3200	0	56	1303	326	0	1828	2416	0	0	277
2024	31	149	93	0	2340	0	0	0	191	0	1400	1624	0	0	295
2025	33	161	95	24	2543	0	36	34	248	0	1616	1683	0	0	315
2026	33	159	94	37	2552	0	67	52	337	0	1628	1730	0	0	336
2027	35	169	97	9	2810	0	0	205	616	0	1795	1775	0	0	0
2028	35	172	97	30	2969	0	41	355	756	0	1844	1864	0	0	0
2029	40	193	109	25	3200	0	0	1111	923	0	2357	2513	0	0	0
2030	40	193	109	35	3200	0	0	1217	1001	0	2359	2829	0	0	0
2031	41	195	109	52	3200	0	44	1244	1143	0	2529	3004	0	0	0
2032	39	190	108	80	3200	0	63	1196	1177	0	2370	2998	0	0	0

Table 10.3.1-3: Base case + 12% discount rate – Annual energy in [GWh/a]

The table above shows the annual energy production per power plant / import line and per year. Diesel based electricity generation until 2026 and coal based electricity from 2027 on is used for peaks but with a relative low load factor.

From 2024 on the load factor of hydro power based imports from TAJ is reduced significantly. In some years load factor of some domestic hydro power plants (Sarobi_HPP and Kajaki_Extension) is reduced. The domestic share of energy generation is increasing until 2032 of approximated 67%.

This aggregated values and shares for domestic/import and HPP/TPP based electricity generation is shown in the next diagram. From 2024 the share of HPP based generation achieves around 50% (between 44% and 55%) of the annual energy generation for Afghanistan.

Annual electricity generation	HPP domestic	TPP domestic	HPP import	TPP import	Total electricity generation	HPP Share	TPP Share	Domestic share	Import share
	[Gwh]	[Gwh]	[Gwh]	[Gwh]	[Gwh]	[%]	[%]	[%]	[%]
2012	1326	468	97	1992	3883	37	63	46	54
2013	1366	569	117	2286	4339	34	66	45	55
2014	1402	697	141	2590	4829	32	68	43	57
2015	1436	837	167	2898	5338	30	70	43	57
2016	1457	781	199	3160	5597	30	70	40	60
2017	1473	1424	235	3491	6624	26	74	44	56
2018	1482	1383	265	4170	7300	24	76	39	61
2019	1486	1506	297	4547	7836	23	77	38	62
2020	1489	1992	1286	4324	9091	31	69	38	62
2021	1489	2400	1300	4452	9640	29	71	40	60
2022	1489	3217	1309	4329	10343	27	73	45	55
2023	1489	3618	1313	4632	11051	25	75	46	54
2024	2969	3543	1071	4148	11732	34	66	56	44
2025	2969	3634	1202	4639	12443	34	66	53	47
2026	7259	2432	0	3471	13162	55	45	74	26
2027	7565	3451	294	4380	15690	50	50	70	30
2028	8042	3619	376	4535	16573	51	49	70	30
2029	8653	5276	1112	6003	21043	46	54	66	34
2030	8657	5651	1214	6209	21732	45	55	66	34
2031	8662	6061	1241	6692	22656	44	56	65	35
2032	9608	6264	1198	6561	23630	46	54	67	33

Table 10.3.1-4: Base case + 12% discount rate –Energy generation shares

10.3.1.4 System costs and average electricity cost

For the evaluation of total generation costs we take in account investment costs of the projected assets. We assumed equal annual rates during the useful_lifetime as annual generation capacity costs. For existing equipment capacity costs are not known in general. Capacity costs for projected import lines, which compete with domestic generation are included as well as costs for the connection of power plants to the grid. OPEX for domestic generation is included as given, especially for all projected generation assets. Fuel costs include costs for the domestic resources coal and natural gas and for diesel. Costs for unserved energy are generally not taken into account.

Annual electricity generation	Total electricity generation	Generation capacity cost	Coal	Diesel	Natural_Gas	Electricity import	OPEX domestic generation	Annual system cost	Average annual cost (including generation capacity cost)	Average annual cost (excluding generation capacity cost)
	[GWh]	[mioUSD]	[mioUSD]	[mioUSD]	[mioUSD]	[mioUSD]	[mioUSD]	[mioUSD]	[USD/MWh]	[USD/MWh]
2012	3881	0	0	30	10	86	17	144	37.0	37.0
2013	4337	0	0	49	11	101	19	179	41.3	41.3
2014	4827	0	0	80	11	116	20	227	47.1	47.1
2015	5335	0	0	114	11	132	22	279	52.2	52.2
2016	5594	0	0	102	11	144	21	278	49.8	49.8
2017	6620	29	0	144	22	162	27	384	58.1	53.7
2018	7297	52	0	25	31	200	27	335	45.9	38.8
2019	7833	52	0	43	32	220	28	376	48.0	41.4
2020	10839	113	0	3	72	290	44	522	48.1	37.7
2021	11388	122	0	6	81	297	47	554	48.6	37.9
2022	12091	193	0	9	79	260	52	594	49.1	33.1
2023	12799	193	0	22	81	290	54	640	50.0	34.9
2024	13472	430	0	0	57	176	61	724	53.8	21.8
2025	14191	430	0	14	62	195	64	765	53.9	23.6
2026	14909	462	0	32	62	205	67	827	55.5	24.5
2027	15685	539	14	2	67	227	75	925	58.9	24.6
2028	16492	539	21	17	71	247	80	975	59.1	26.4
2029	20842	740	100	6	80	342	121	1389	66.6	31.1
2030	21725	740	120	8	80	366	130	1445	66.5	32.4
2031	22649	740	138	23	81	393	139	1514	66.8	34.2
2032	23618	811	148	40	80	385	149	1613	68.3	33.9

Table 10.3.1-5: Base case + 12% discount rate – System costs and average electricity cost

The table above presents the calculated data. The average annual electricity cost - including annual generation capacity costs - increase from 37 USD/MWh in 2012 to 68.3 USD/MWh in 2032. A significant part of the increase towards the end of the planning period is caused by relative high costs of the Bamyan coal power plant.

The weighted average electricity cost over the complete planning period is estimated as 52.5 USD/MWh in the base variant. It includes annual capacity generation costs for projected assets, but it does not include general costs for grid transmission and distribution and it does not include capacity costs for existing assets. The weight factors are chosen according to an annual discount rate of 12 %.

The last column shows the average annual operation cost including fuel costs excluding capacity costs. The average annual operating cost varies in dependency of the generation portfolio and the overall load factor, especially after production start of large units. A Minimum of 21.8 USD/MWh is achieved in 2024 and the maximum of 53.7 occurs in 2017.

The maximum in 2017 results from a high diesel share. The minimum in 2024 results from a high load factor and minimized diesel based electricity generation.

The following table presents the calculation for the generation capacity costs.

	Baghdara_HPP	Bamyan_TPP_el	Gulbahar_HPP	Kajaki_Addition_HPP	Kama_HPP	Kilagai_HPP	Kukcha_HPP	Kunar_A_HPP	Kunar_B_HPP	Olambagh_HPP	Sheberghan_TPP_el	Surobi_HPP	TKM_2_NEPS_UZB_add_import	TKM_2_NEPS_UZB_import	Sum
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	29	0	0	0	29
2018	0	0	0	0	0	0	0	0	0	0	38	0	0	14	52
2019	0	0	0	0	0	0	0	0	0	0	38	0	0	14	52
2020	0	0	0	0	0	0	0	0	0	0	67	0	23	23	113
2021	0	0	0	0	0	0	0	0	0	0	77	0	23	23	122
2022	0	0	0	0	0	0	0	0	71	0	77	0	23	23	193
2023	0	0	0	0	0	0	0	0	71	0	77	0	23	23	193
2024	0	0	0	0	0	0	0	236	71	0	77	0	23	23	430
2025	0	0	0	0	0	0	0	236	71	0	77	0	23	23	430
2026	0	0	0	32	0	0	0	236	71	0	77	0	23	23	462
2027	0	77	0	32	0	0	0	236	71	0	77	0	23	23	539
2028	0	77	0	32	0	0	0	236	71	0	77	0	23	23	539
2029	0	231	0	32	0	0	0	236	71	47	77	0	23	23	740
2030	0	231	0	32	0	0	0	236	71	47	77	0	23	23	740
2031	0	231	0	32	0	0	0	236	71	47	77	0	23	23	740
2032	71	231	0	32	0	0	0	236	71	47	77	0	23	23	811

Table 10.3.1-6: Base case + 12% discount rate – Annual generation capacity costs in [mioUSD/a]

10.3.1.5 Dispatching

The graphs below show dispatching of all generation units in Afghanistan and all electricity imports in 2015, 2020, 2025 and 2032.

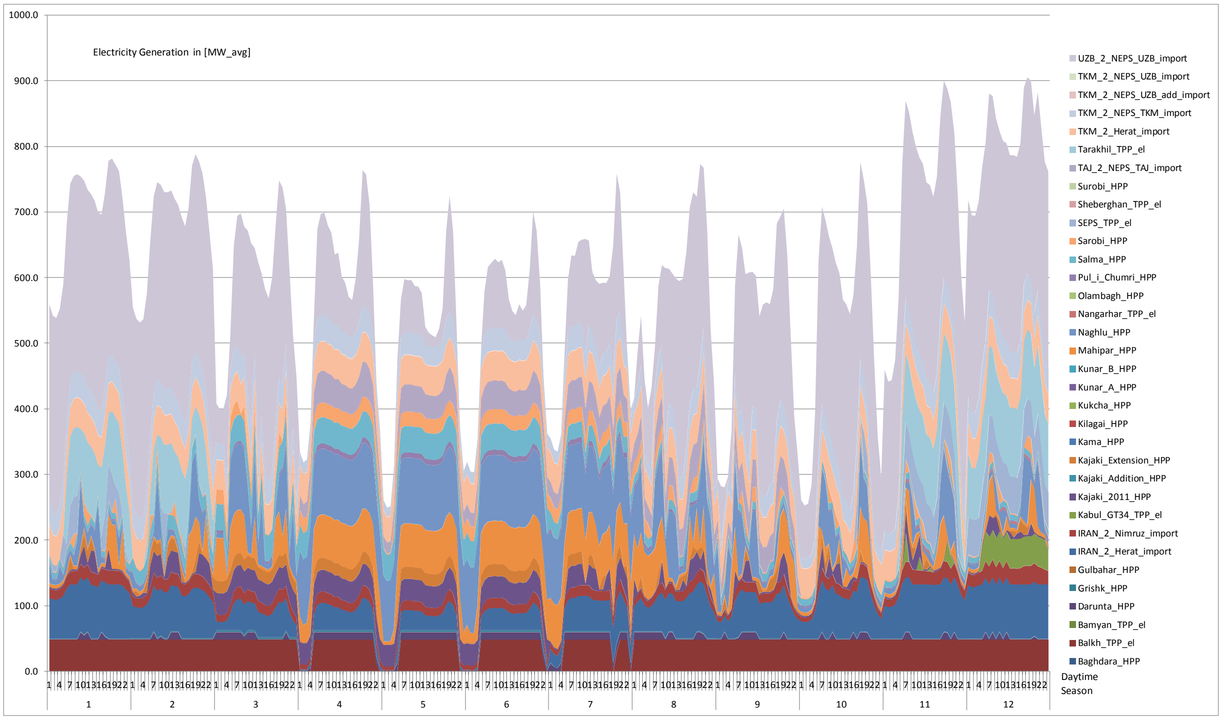


Figure 10.3.1-2: Base case + 12% discount rate - Schedule 2015 in [MW]

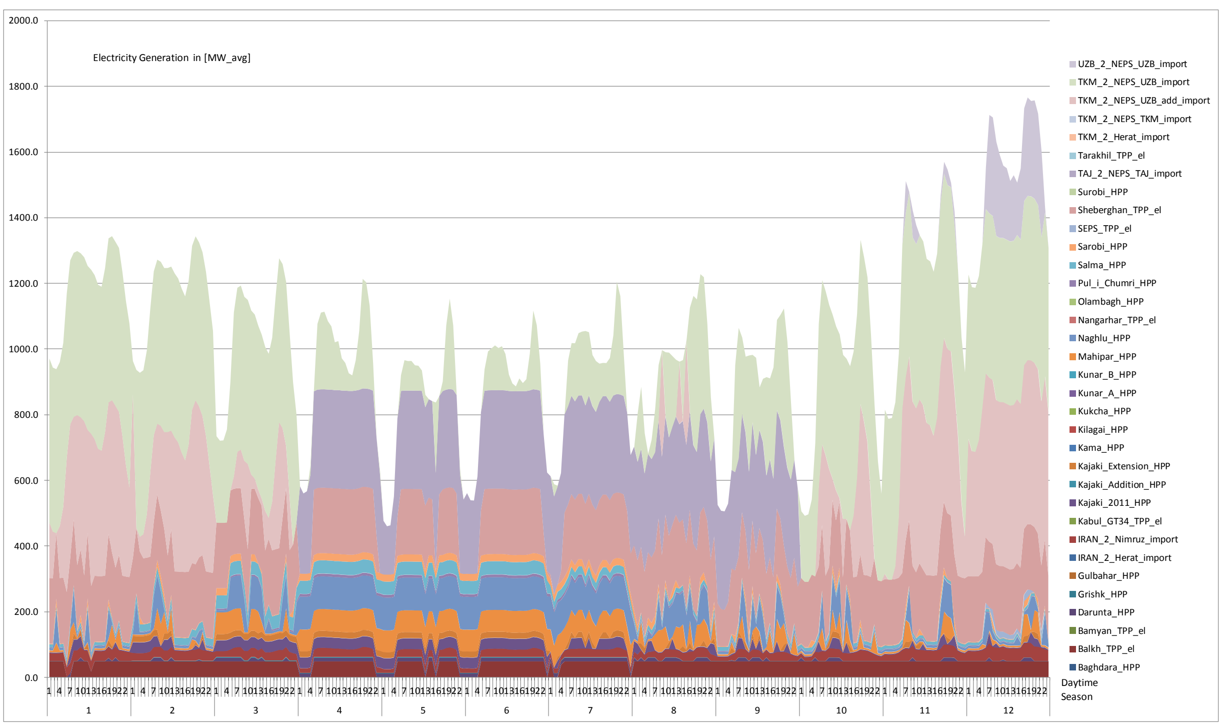


Figure 10.3.1-3: Base case + 12% discount rate - Schedule 2020 in [MW]

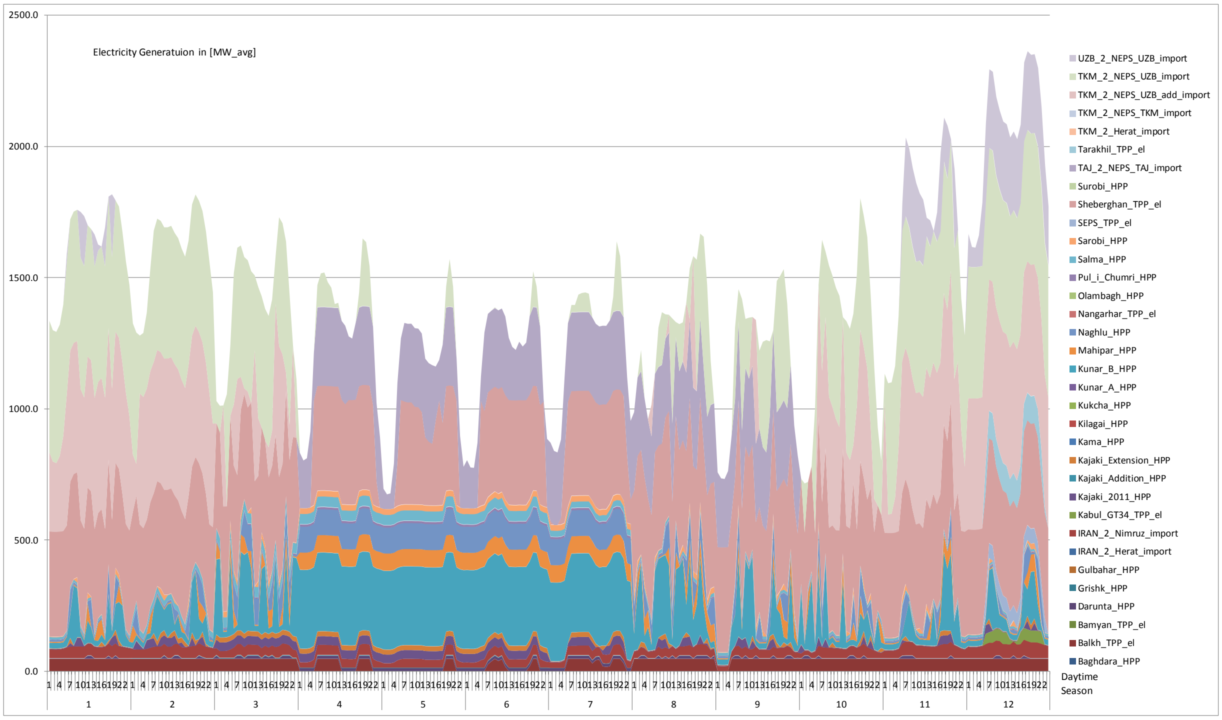


Figure 10.3.1-4: Base case + 12% discount rate - Schedule 2025 in [MW]

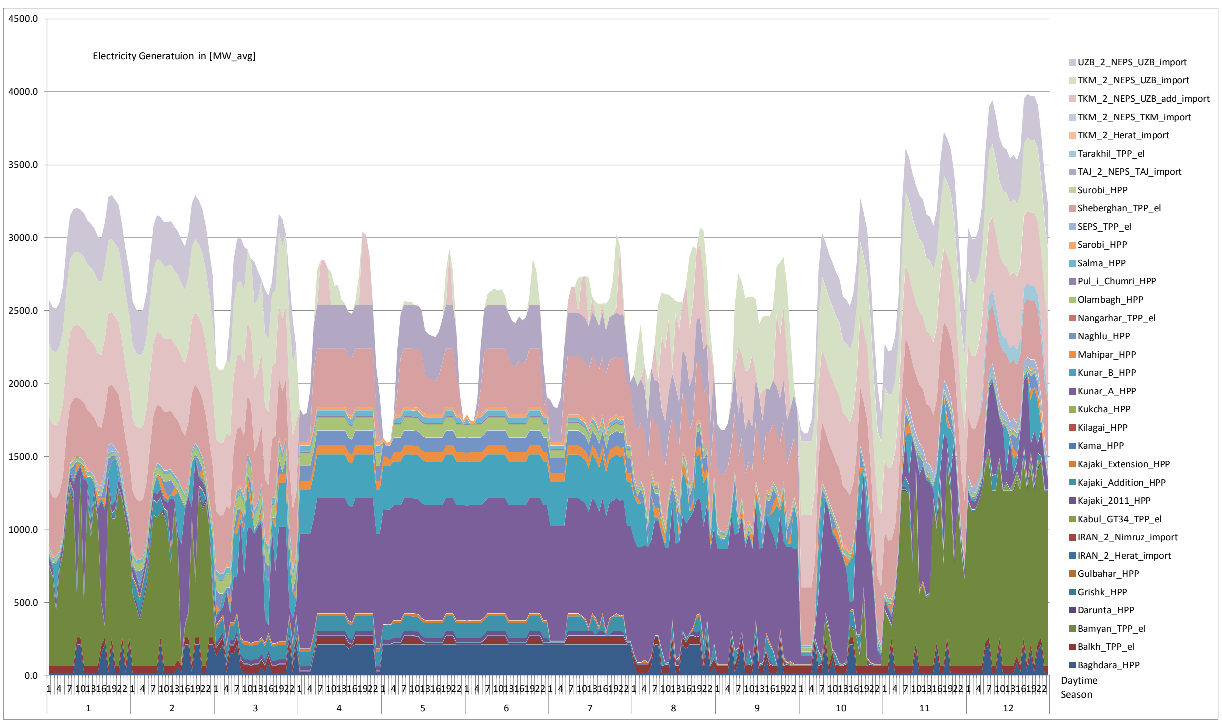


Figure 10.3.1-5: Base case + 12% discount rate - Schedule 2032 in [MW]

The graphs show the development of the overall energy system, with each showing generation for one year. For every season (month) we entered one day of 24 hours. Due to the high rise in demand and high information density, we applied differing scaling for the power axis.

The graph for 2015 shows the initial configuration and a high share of **unserved demand**. During 2020 and 2025, the full demand is served. In 2032, there is unserved demand during peak times.

All graphs show extensive use of the **day storage** capabilities of some HPPs and cycling, especially to cater for peak load in winter. Dispatching in summer is dominated by HPP generation whereas dispatching in winter is dominated by thermal generation.

The graph for 2032 shows low **load factors** for thermal based electricity generation. The load for the coal-fired power plants (Bamyan_el) may increase with slightly different OPEX values. On the other hand, this may result in higher import tariffs, because of low load factors. The expansion order indicates an economic advantage for (not available) additional gas-based power plants. The graphs indicate high potentials for load shifting, annual storage capacities and electricity export in summer. The graphs in the following subchapters show the findings in more detail.

10.3.1.6 Unserved demand

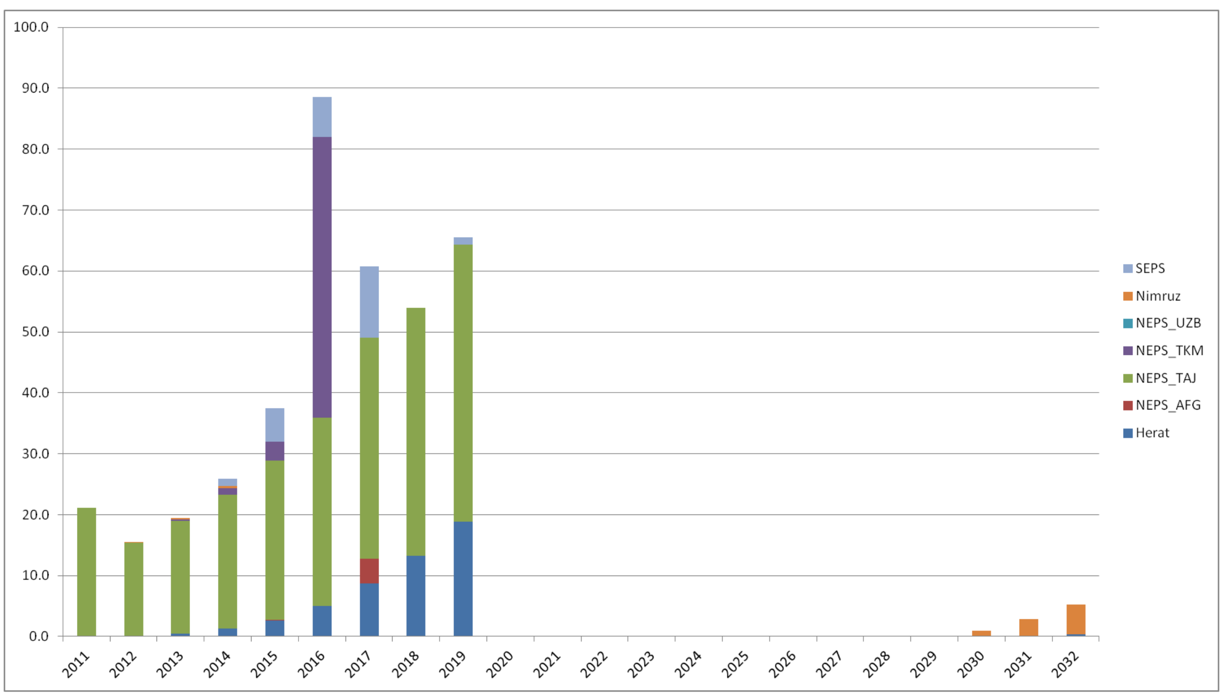


Figure 10.3.1-6: Base case + 12% discount rate - Unserved demand in [MW avg]

The above graph shows unserved demand (average power) during the planning period. The distribution of unserved energy in connected NEPS areas may be affected by different pricing for unserved energy for different grid segments. The unserved demand in NEPS TAJ up to

2019 results partially from simplifications in the model. Imports from TAJ for various grid islands are generally restricted to summer. The actual system may operate differently up to 2019, but the simplification does not influence the capacity expansion plan.

For other NEPS TKMs, there is a steep increase up to 2016. The gas-fired power plant in Sheberghan and the import line from TKM start operation from 2017 and 2018 respectively. The graph shows that grid capacity from TKM and generation capacity in Sheberghan is required. The increase of unserved demand in Herat from 2014 to 2019 is a clear indication for the need for the planned grid connection to Herat.

The import line from TKM (1 GW) starts operation in 2020. From 2020 to 2029, the demand of all grid segments is served. The capacity expansion starts with Sheberghan, and continues with Kunar HPP. Beginning in 2030 there is unserved demand in the Nimruz / SEPS region. This is due to grid restrictions and restricted generation capacities in this region. The graph below shows the seasonal and regional dependencies of the unserved demand in 2032.

Figure 10.3.1-7: Base case + 12% discount rate –unserved demand 2032 in [MW]

10.3.1.7 Hydro versus thermal generation

The graphs below show the seasonal dependencies of thermal and hydro based electricity generation. The first two graphs show the dependencies in 2032 and the following graphs show thermal generation in 2015, 2020 and 2025. The seasonal dependency of thermal generation is an indication of low load factors resulting in high capacity costs.

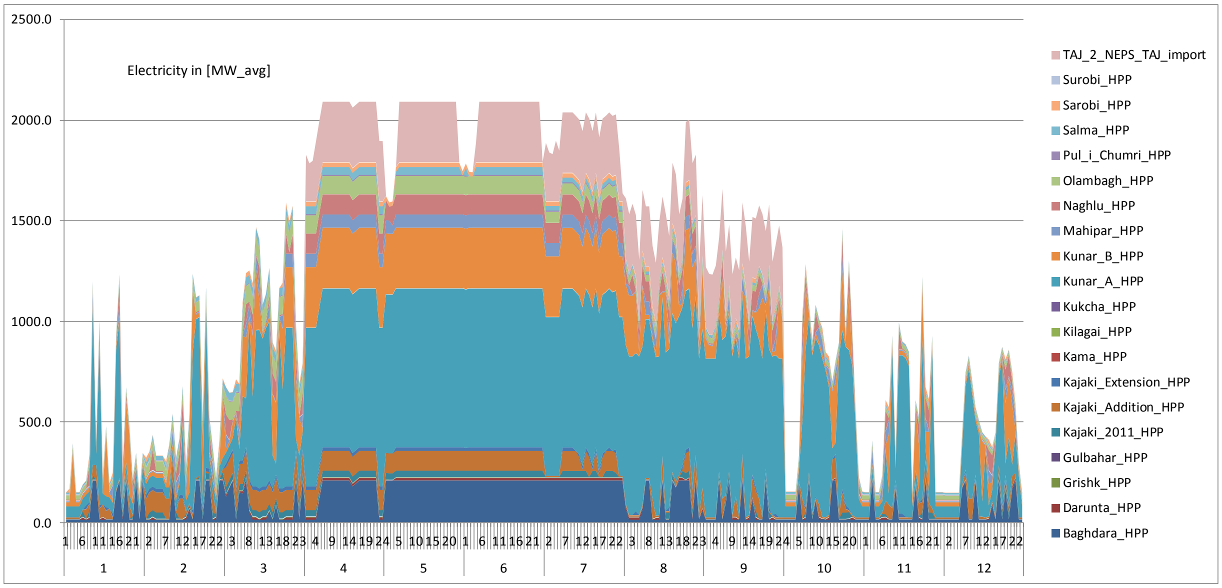


Figure 10.3.1-8: Base case + 12% discount rate - hydro generation 2032 in [MW]

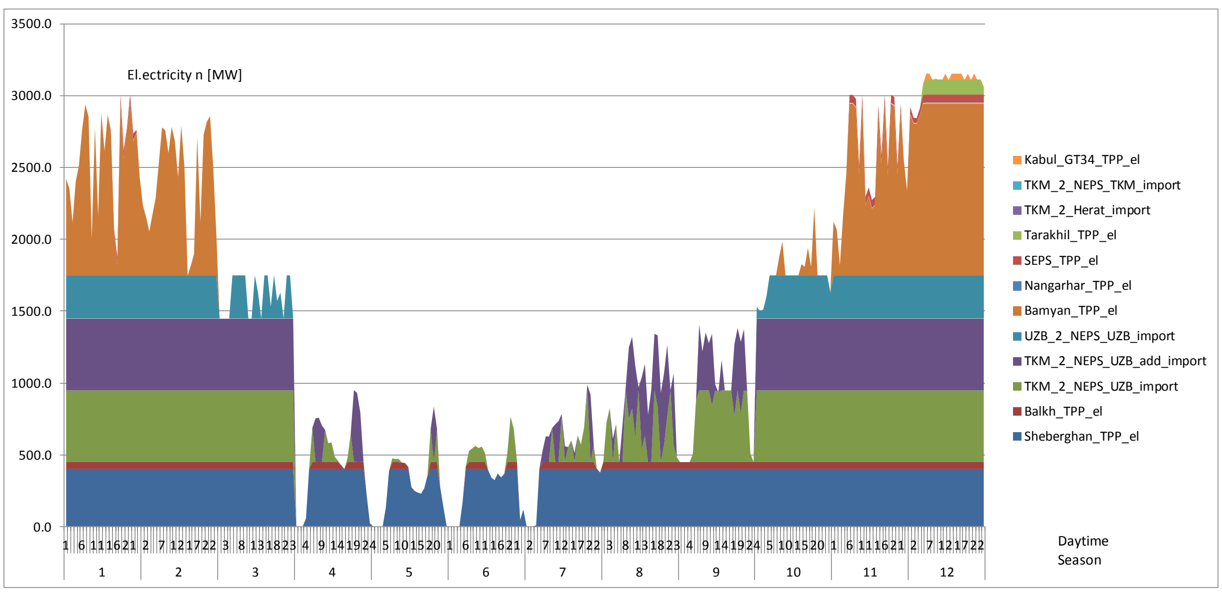


Figure 10.3.1-9: Base case + 12% discount rate - thermal generation 2032 in [MW]

The above graphs show the conjunction of thermal and hydro generation. Hydro generation has a clear maximum in summer and a very extensive usage of day storages in winter for peak lopping. The load of thermal generation is very low due to very high hydro generation in summer. In our expectation, an additional thermal power plant instead of HPP capacity, for instance based on TAPI, should enhance the load factor of thermal power plants and increase the cost effectiveness of the overall system.

Operation of all import options, the coal-fired power plants (Bamyan TPP) and excessive operation of diesel based generation in Kabul and SEPS indicate a capacity limit for the overall system in December. The low thermal based generation in summer is a clear indication that HPP expansion is a result of a lack of alternative options.

The load of the Bamyan TPP may be increased in conjunction with a reduction of electricity imports.

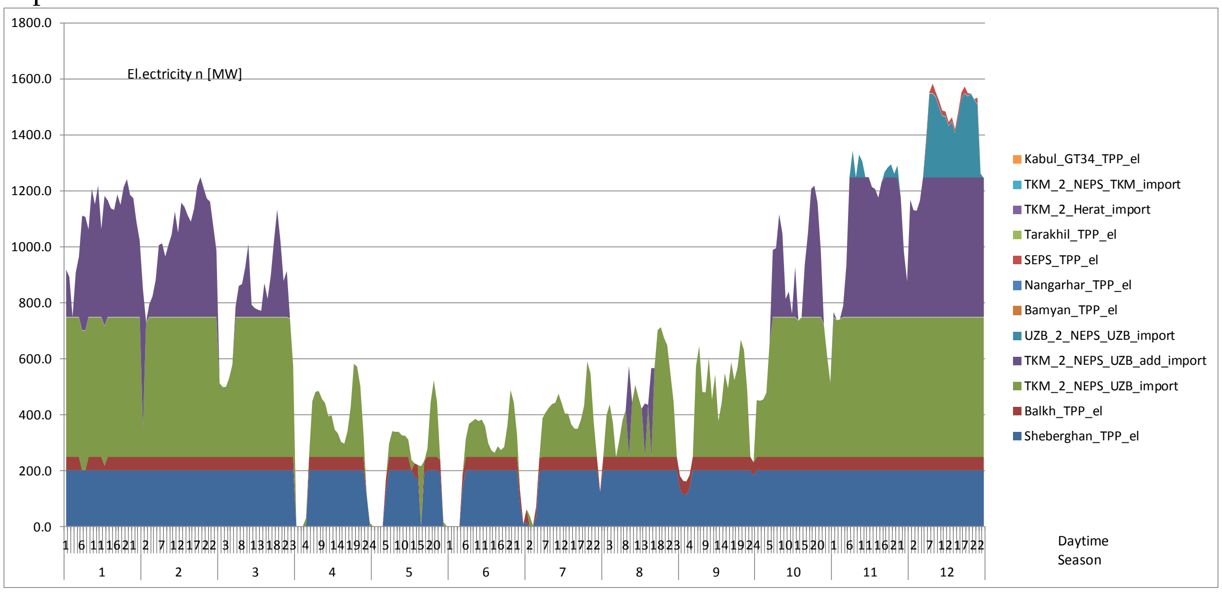


Figure 10.3.1-10: Base case + 12% discount rate - thermal generation 2020 in [MW]

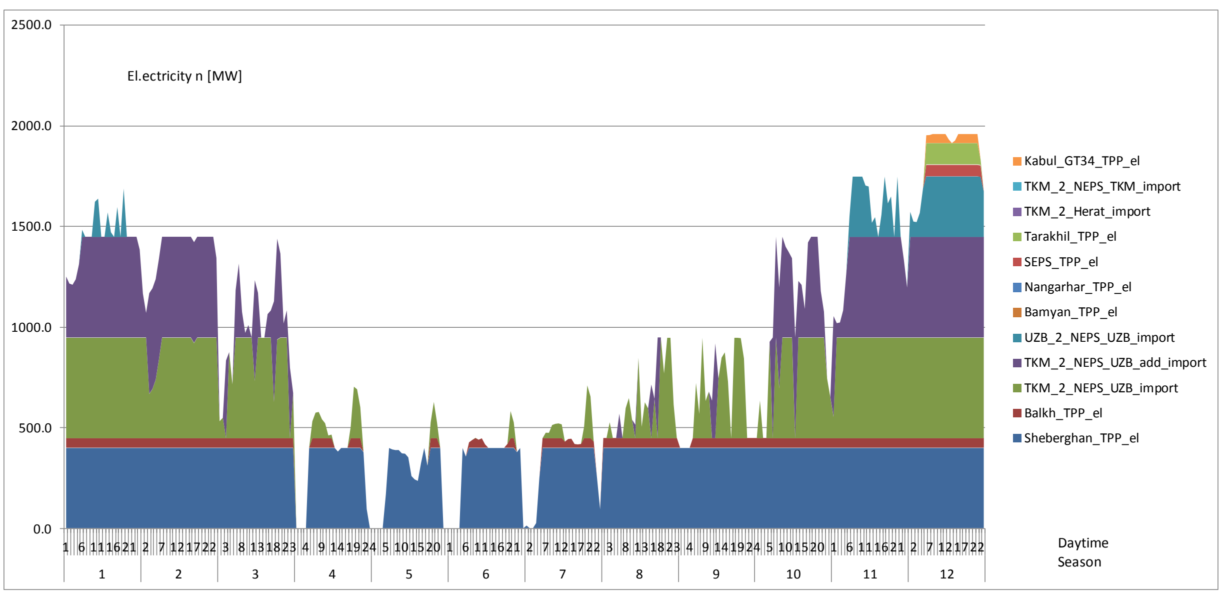


Figure 10.3.1-11: Base case + 12% discount rate - thermal generation 2025 in [MW]

The above graphs show thermal based electricity generation in 2020 and 2025, including thermal based electricity imports. The system is dominated by electricity generation in Sheberghan and electricity imports from TKM and UZB. In 2025, operation of diesel based TPP (SEPS TPP, Tarakil TPP and Kabul GT34 TPP) in December indicate system limits at peak times.

HPP characteristics lead to low loads in summer with resulting with resulting high specific capacity costs.

10.3.1.8 Grid connections

This subchapter presents electricity flows in the main grid connections.

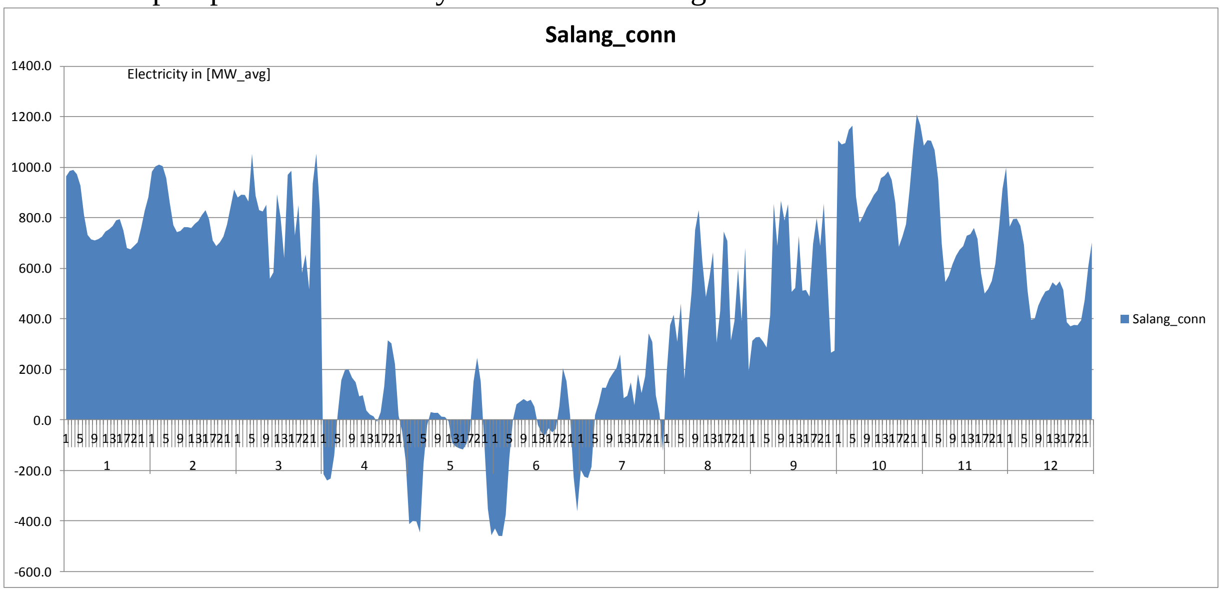


Figure 10.3.1-12: Base case + 12% discount rate - load flow via Salang connection 2032 in [MW]

The above graph shows seasonal and day dependency of the Salang Connection in 2032, with electricity flow from NEPS UZB to NEPS AFG (Kabul). In winter the Salang Connection is used for electricity imports from TKM to Kabul. During the summer months, the connection is used for compensation of hydro generation across NEPS.

The graph below shows electricity flows from NEPS to SEPS. In winter, the connection reaches its limit and the flow is restricted by the line capacity. In summer, electricity transport to SEPS is reduced to match existing hydro capacities. It has to be taken in account that, in 2032, Nimruz demand is served via SEPS.

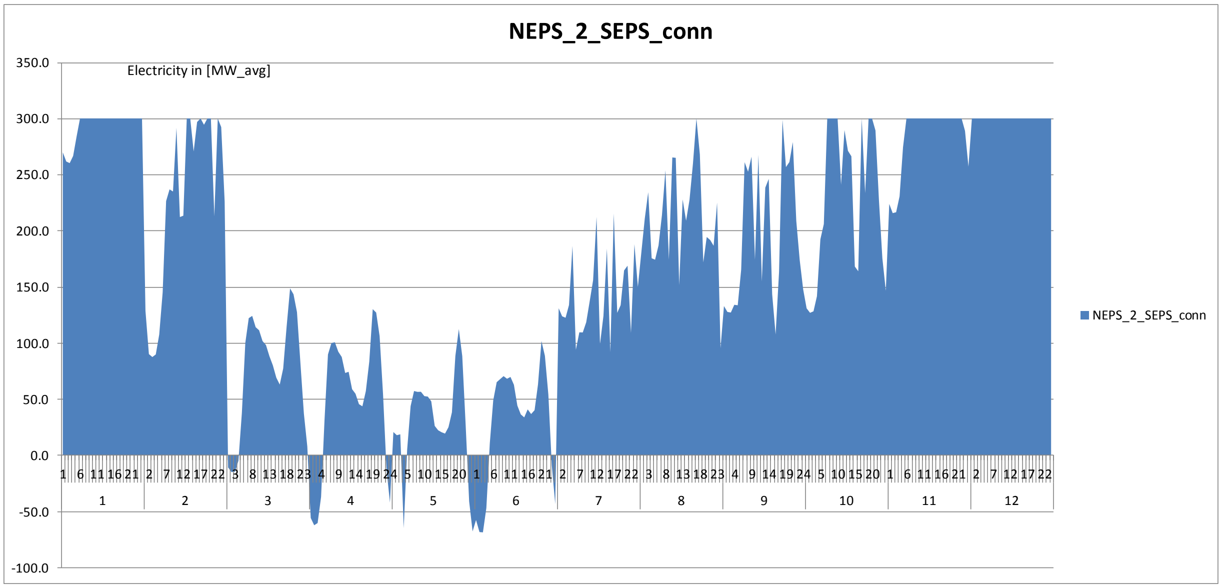


Figure 10.3.1-13: Base case + 12% discount rate - load flow from NEPS to SEPS 2032 in [MW]

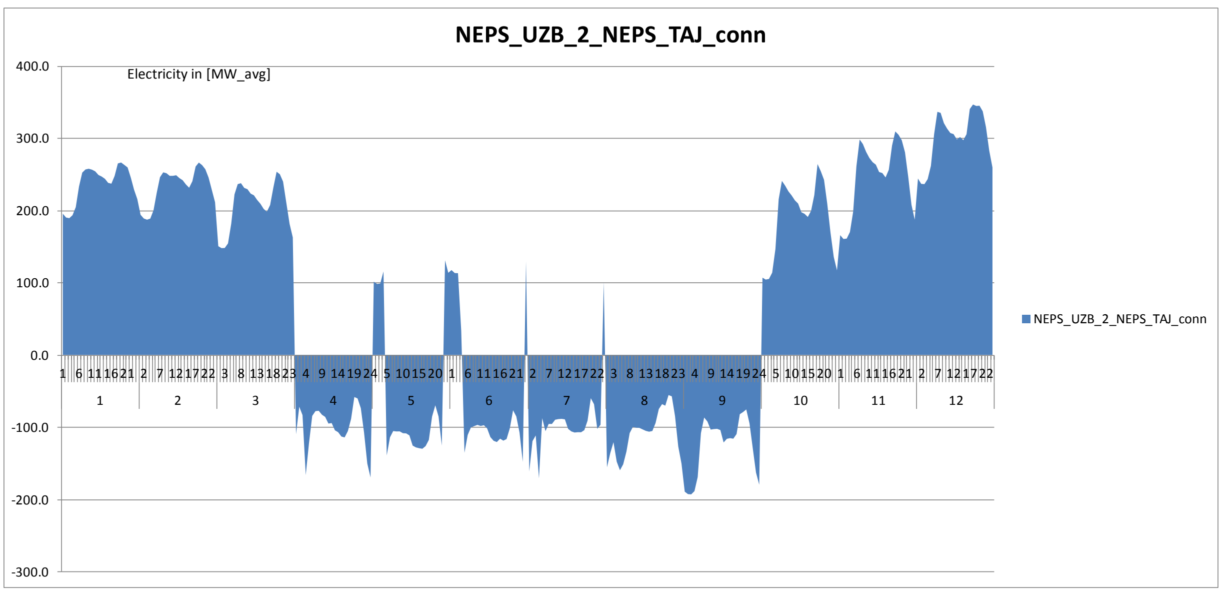


Figure 10.3.1-14: Base case + 12% discount rate - load flow from NEPS UZB to NEPS TAJ 2032 in [MW]

The above graph shows an electricity flow from NEPS UZB to NEPS TAJ in winter and a flow from NEPS TAJ to NEPS UZB in summer. This is caused by high hydro based imports from TAJ.

The graph below shows electricity transport from NEPS UZB to NEPS TKM. The capacity of Sheberghan is not sufficient to serve the additional demand in Herat.

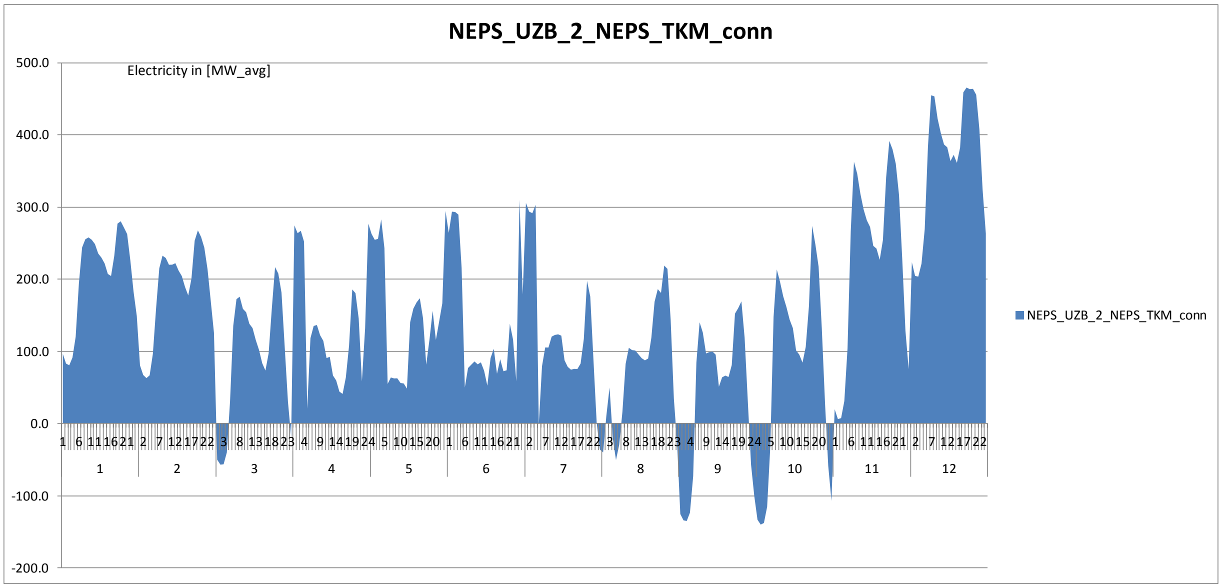


Figure 10.3.1-15: Base case + 12% discount rate - load flow from NEPS UZB to NEPS TKM 2032 in [MW]

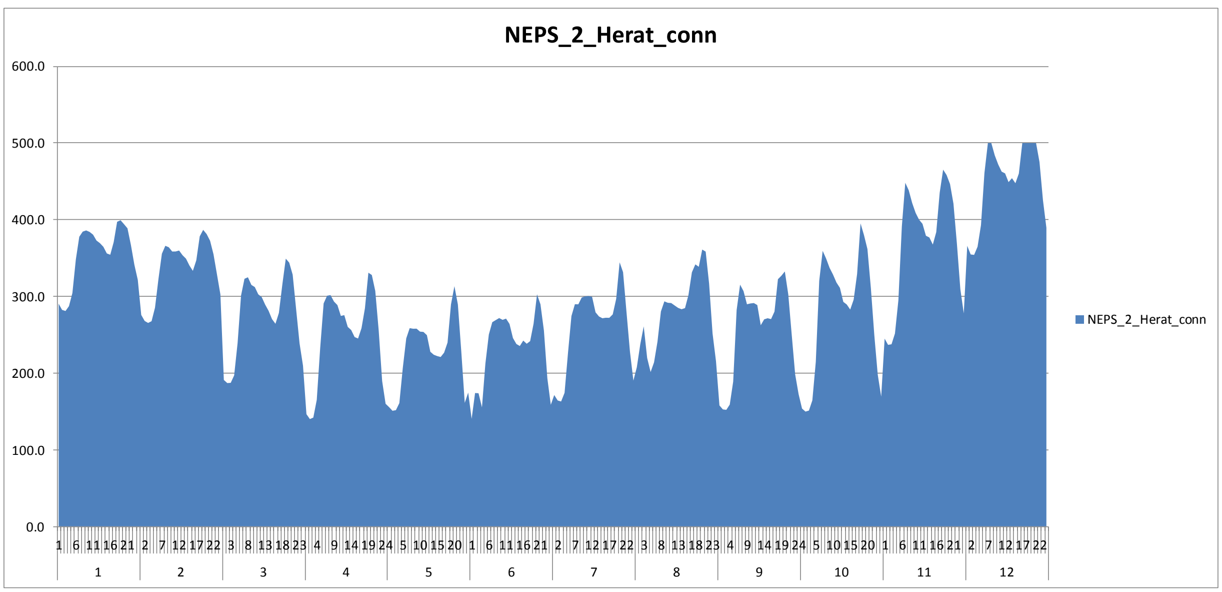


Figure 10.3.1-16: Base case + 12% discount rate - load flow from NEPS TKM to Herat 2032 in [MW]

The above graph shows electricity transport from NEPS to Herat in 2032. Electricity flow to Herat during peak times in December is restricted by line capacity. The graph below shows electricity transport from SEPS to Nimruz in 2032.

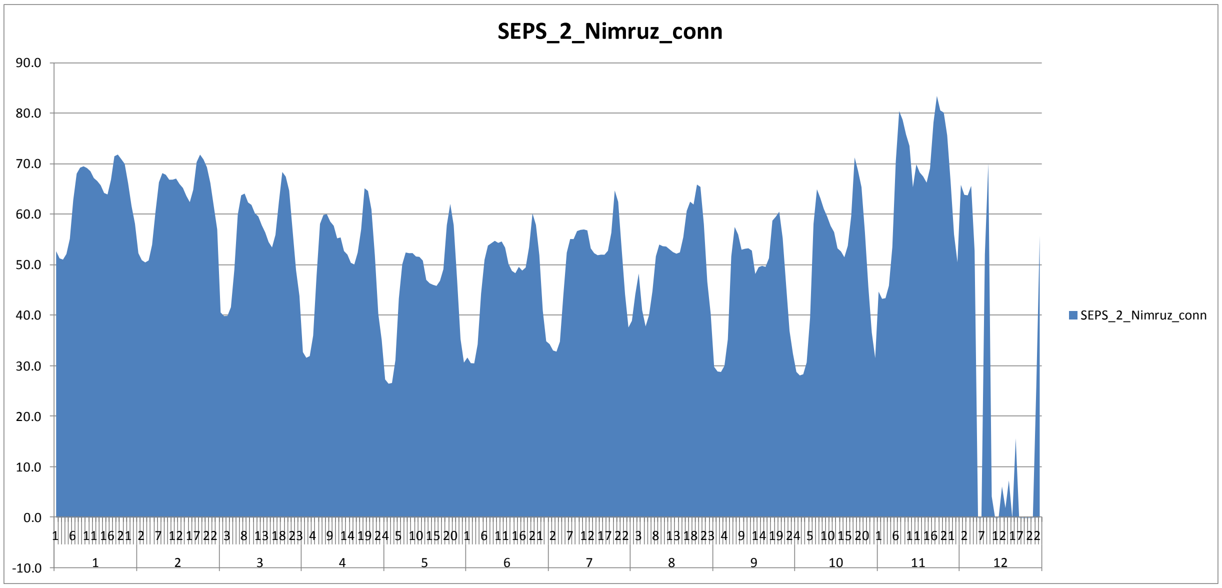


Figure 10.3.1-17: Base case + 12% discount rate - load flow from SEPS to Nimruz 2032 in [MW]

10.3.2 High case, 12% discount rate

This variant is based on the demand high case and a discount rate of 12%.

10.3.2.1 Capacity expansion planning

The table and graph below show capacity expansion planning for the high case scenario. In 2028, all options are in operation.

The second stage from 150 MW to 300 MW of the connection from **NEPS to SEPS** starts operating in 2022. Operation for the base case starts in 2023. This indicates a robust decision with linear sensitivity.

Expansion of Sheberghan TPP capacity is identical until 2019. Maximum capacity starts operation in 2021 in comparison to 2023 for the base variant. In view of the raised demand, the increase indicates a robust decision with linear sensitivity. The expansion order of TKM imports and most of the HPP capacity is identical with the base variant but due to increased demand, the start of operation is earlier. In conjunction with the base variant, operation of Baghdara HPP and Kukcha HPP starts before Kajaki Addition HPP and Olambagh HPP. The reason for this is the higher demand. As a consequence, the construction sequence of the two SEPS HPPs difference between the two variants. Construction of the high case depends more on the cost structure and less on unit size than the base variant. A sufficient share of HPP with day storage results in improved cost effectiveness for the overall system.

	Baghdara_HPP	Bamyan_TPP_el	Gulbahar_HPP	Kajaki_Addition_HPP	Kama_HPP	Kilagai_HPP	Kukcha_HPP	Kunar_A_HPP	Kunar_B_HPP	NEPS_2_SEPS_conn	Olambagh_HPP	Sheberghan_TPP_el	Surobi_HPP	TKM_2_NEPS_UZB_add_import	TKM_2_NEPS_UZB_import
2011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	150.0	0.0	0.0	0.0	0.0	0.0
2017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	150.0	0.0	150.0	0.0	0.0	0.0
2018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	150.0	0.0	200.0	0.0	0.0	300.0
2019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	150.0	0.0	200.0	0.0	0.0	300.0
2020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	150.0	0.0	350.0	0.0	500.0	500.0
2021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	150.0	0.0	400.0	0.0	500.0	500.0
2022	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	300.0	300.0	0.0	400.0	0.0	500.0	500.0
2023	0.0	0.0	0.0	0.0	0.0	0.0	0.0	789.0	300.0	300.0	0.0	400.0	0.0	500.0	500.0
2024	0.0	0.0	0.0	0.0	0.0	0.0	0.0	789.0	300.0	300.0	0.0	400.0	0.0	500.0	500.0
2025	210.0	0.0	0.0	0.0	0.0	0.0	0.0	789.0	300.0	300.0	0.0	400.0	0.0	500.0	500.0
2026	210.0	0.0	0.0	0.0	0.0	0.0	445.0	789.0	300.0	300.0	0.0	400.0	0.0	500.0	500.0
2027	210.0	400.0	0.0	100.0	0.0	0.0	445.0	789.0	300.0	300.0	90.0	400.0	0.0	500.0	500.0
2028	210.0	400.0	120.0	100.0	45.0	60.0	445.0	789.0	300.0	300.0	90.0	400.0	180.0	500.0	500.0
2029	210.0	1200.0	120.0	100.0	45.0	60.0	445.0	789.0	300.0	300.0	90.0	400.0	180.0	500.0	500.0
2030	210.0	1200.0	120.0	100.0	45.0	60.0	445.0	789.0	300.0	300.0	90.0	400.0	180.0	500.0	500.0
2031	210.0	1200.0	120.0	100.0	45.0	60.0	445.0	789.0	300.0	300.0	90.0	400.0	180.0	500.0	500.0
2032	210.0	1200.0	120.0	100.0	45.0	60.0	445.0	789.0	300.0	300.0	90.0	400.0	180.0	500.0	500.0

Table 10.3.2-1: High case + 12% discount rate - capacity expansion in [MW

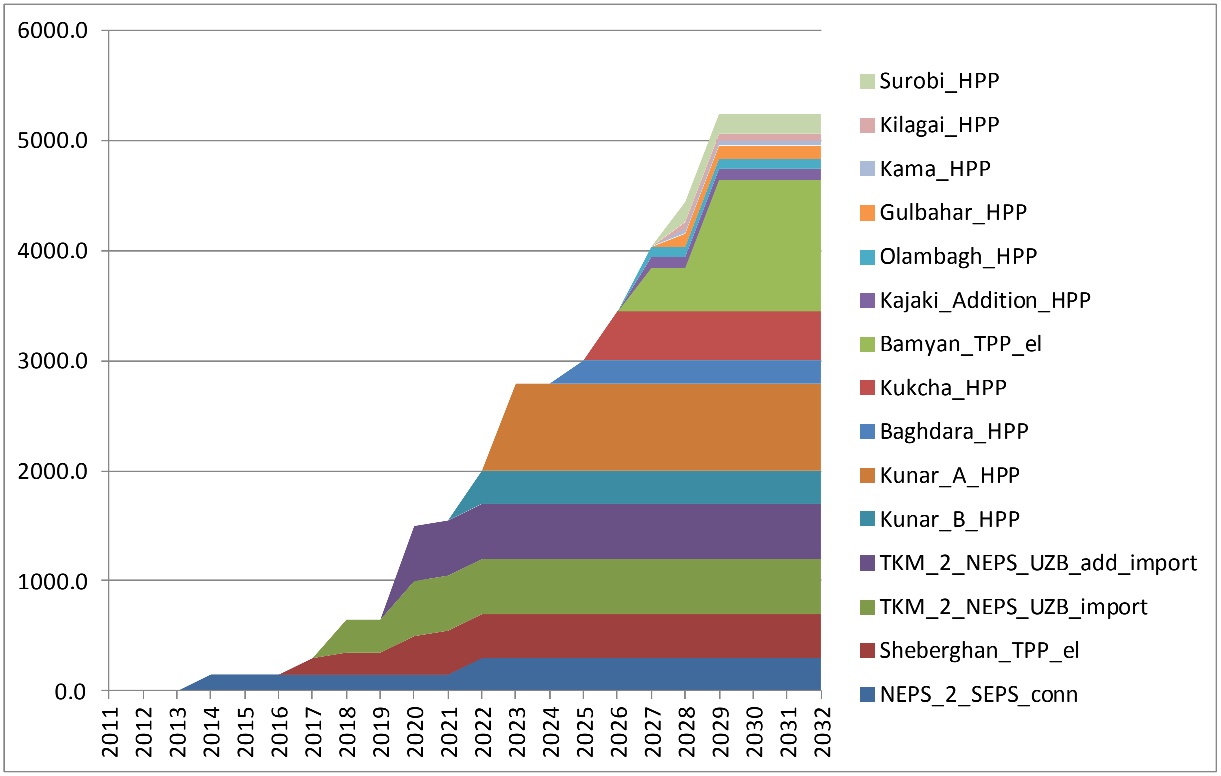


Figure 10.3.2-1: High case + 12% discount rate - capacity expansion in [MW]

10.3.2.2 Costs of the projects

The table below show the investment cost for the high case variant and 12% discount rate.

Period	Invest	Discount_ factor	NPV
	[mioUSD]	[1]	[mioUSD]
2012	0	1.000	0
2013	0	0.893	0
2014	0	0.797	0
2015	0	0.712	0
2016	100	0.636	63.6
2017	255	0.567	145
2018	212	0.507	108
2019	0	0.452	0
2020	552	0.404	223
2021	85	0.361	31
2022	760	0.322	245
2023	2200	0.287	632
2024	0	0.257	0
2025	660	0.229	151
2026	1540	0.205	315
2027	1420	0.183	259
2028	1723	0.163	281
2029	1360	0.146	198
2030	0	0.130	0
2031	0	0.116	0
2032	0	0.104	0
Sum	**10867**		**2652**

Table 10.3.2-2: High case + 12% discount rate - costs for capacity expansion in [m USD]

10.3.2.3 Dispatching

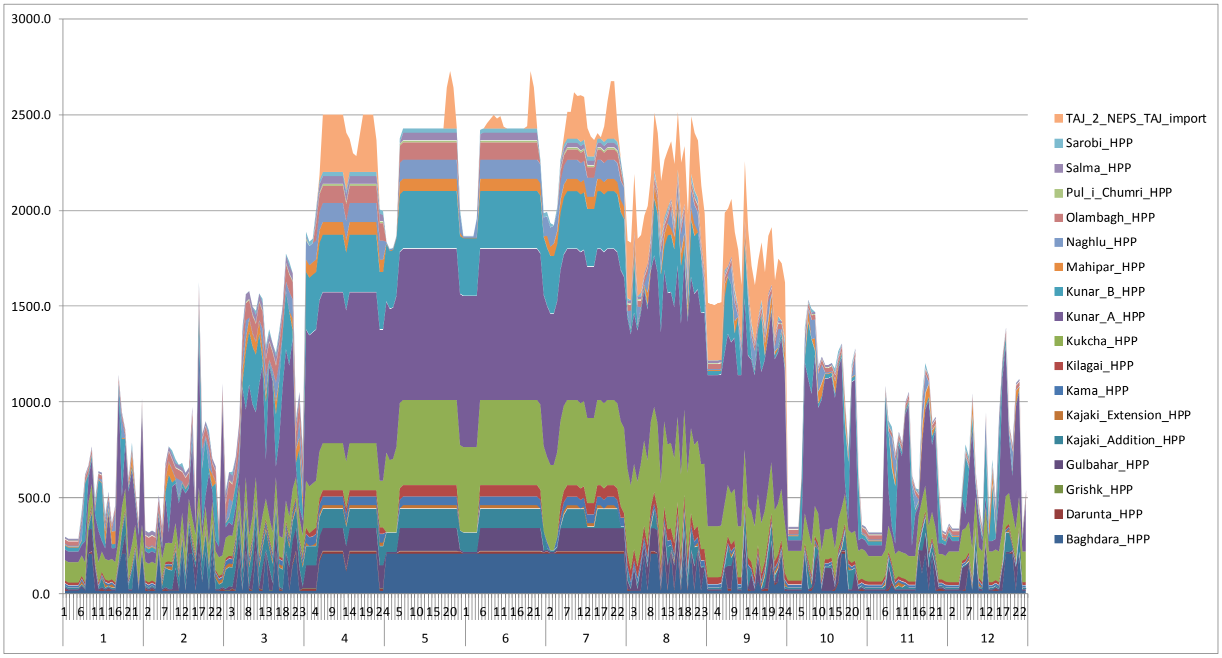


Figure 10.3.2-2: High case + 12% discount rate - HPP schedule 2032 in [MW]

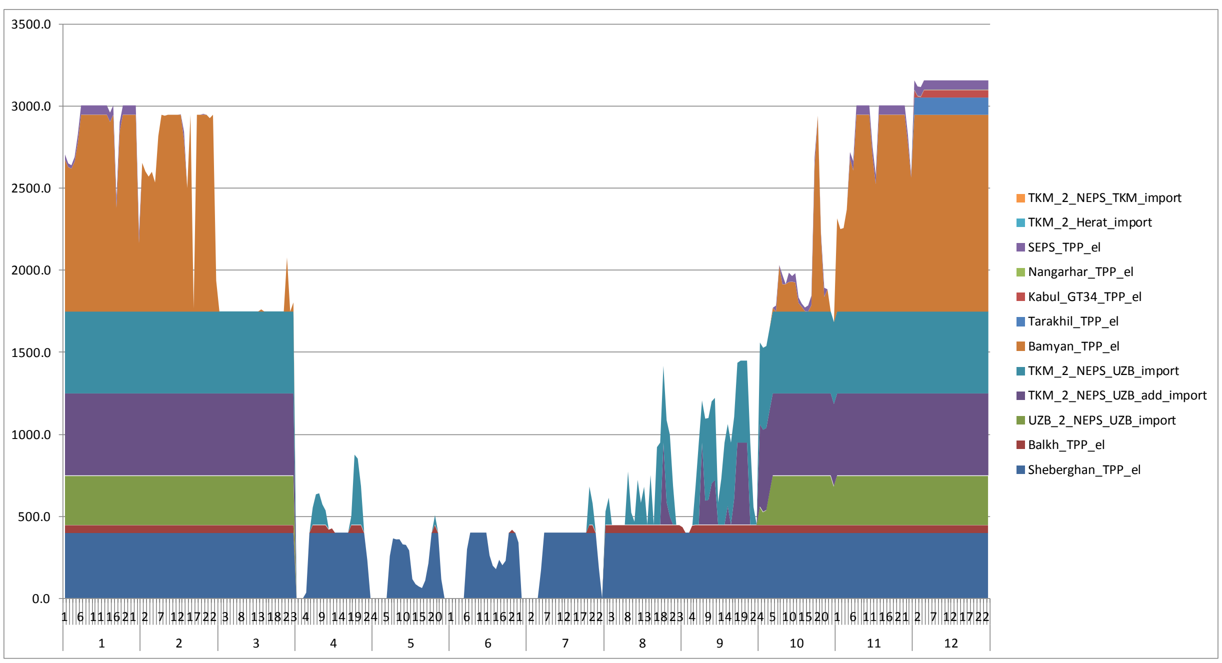


Figure 10.3.2-3: High case + 12% discount rate - TPP schedule 2032 in [MW]

The two graphs above show dispatching of hydro and thermal based generation. The underlying generation structure is comparable with the base variant. Generation is restricted by capacity throughout December. The domination of HPP generation in summer and TPP generation in winter is more extreme than in the base variant. The thermal load during summer including thermal based imports is very low. This indicates a low load for the overall system and high capacity costs. A lack of alternative generation options means that HPP capacity expansion satisfies peak demand despite an HPP load factor of between 20 and 30% at peak times! In the high case, alternative options are highly welcome:

- efficiency improvements e.g. demand management
- load shifting, e.g. enhanced annual hydro storages
- TAPI based gas power plants to substitute HPP capacity
- additional TPP based imports, e.g. from TKM
- additional exports to PAK.

10.3.2.4 Unserved demand

The graph below shows the development of unserved demand over time. This development is similar to the base variant, but at a higher level. Up to 2020, the unserved demand is due to structural deficits.

The unserved demand in NEPS TAJ up to 2019 results partially from simplifications in the model. Imports from TAJ for various grid islands are generally restricted to summer. The actual system may operate differently up to 2019, but the simplification does not influence the capacity expansion plan.

Starting in 2028, the existing options are not capable of serving the demand of the overall system during all peak times. Additional grid constraints in the SEPS Nimruz regions (NEPS 2_SEPS_conn) and in the Herat regions (NEPS 2_Herat_conn) exceed their limits during peak times.

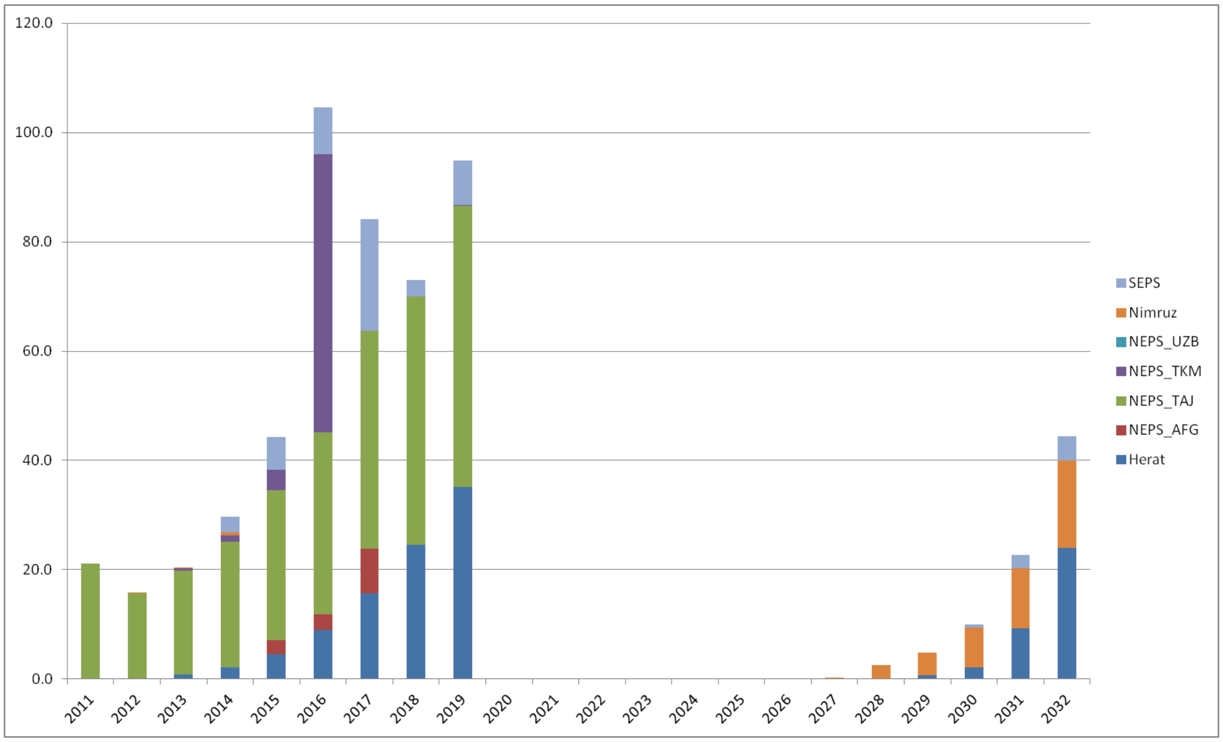


Figure 10.3.2-4: High case + 12% discount rate - unserved demand in [MW]

10.3.3 Low case, 12% discount rate

This variant is based on the demand low case and a discount rate of 12%.

10.3.3.1 Capacity expansion plan

	NEPS_2_SEPS_conn	Sheberghan_TPP_el	TKM_2_NEPS_UZB_import	TKM_2_NEPS_UZB_add_import	Bamyan_TPP_el	Kunar_B_HPP	Baghdara_HPP	Gulbahar_HPP	Kajaki_Addition_HPP	Kama_HPP	Kilagai_HPP	Kukcha_HPP	Kunar_A_HPP	Olambagh_HPP	Surobi_HPP
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	150	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	150	100	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	150	150	300	0	0	0	0	0	0	0	0	0	0	0	0
2019	150	200	300	0	0	0	0	0	0	0	0	0	0	0	0
2020	150	200	500	500	0	0	0	0	0	0	0	0	0	0	0
2021	150	200	500	500	0	0	0	0	0	0	0	0	0	0	0
2022	150	200	500	500	0	0	0	0	0	0	0	0	0	0	0
2023	150	200	500	500	0	0	0	0	0	0	0	0	0	0	0
2024	150	250	500	500	0	0	0	0	0	0	0	0	0	0	0
2025	150	300	500	500	0	0	0	0	0	0	0	0	0	0	0
2026	150	350	500	500	0	0	0	0	0	0	0	0	0	0	0
2027	300	400	500	500	400	300	0	0	0	0	0	0	0	0	0
2028	300	400	500	500	400	300	0	0	0	0	0	0	0	0	0
2029	300	400	500	500	1200	300	0	0	0	0	0	0	0	0	0
2030	300	400	500	500	1200	300	0	0	0	0	0	0	0	0	0
2031	300	400	500	500	1200	300	0	0	0	0	0	0	0	0	0
2032	300	400	500	500	1200	300	0	0	0	0	0	0	0	0	0

Table 10.3.3-1: Low case + 12% discount rate - capacity expansion in [MW]

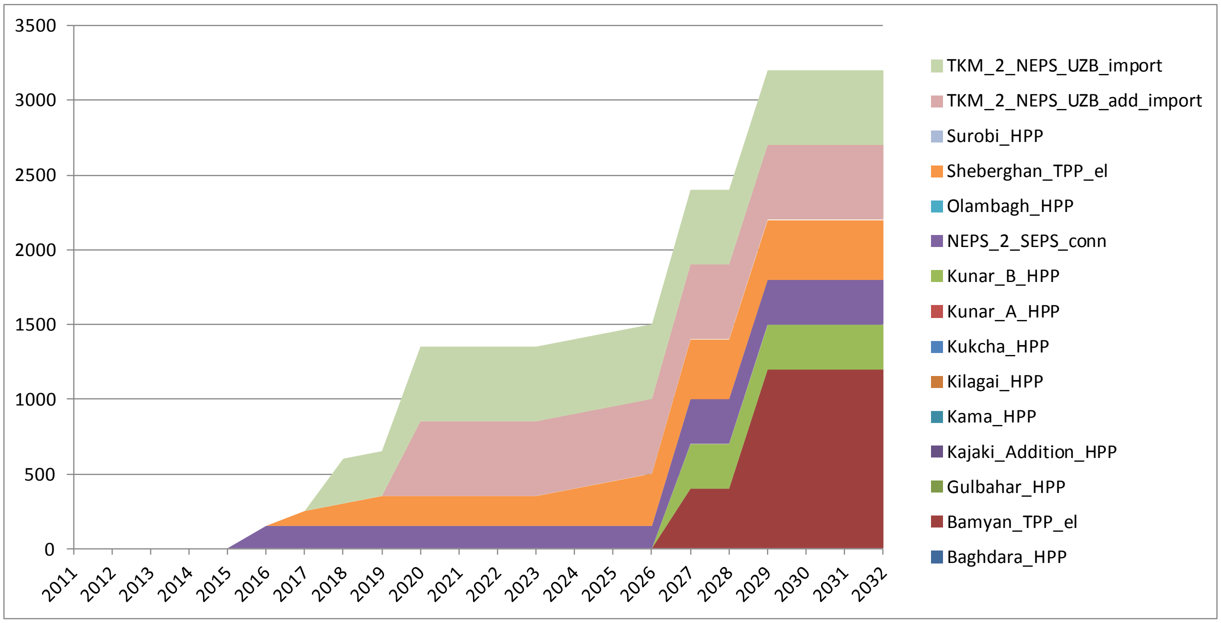


Figure 10.3.3-1: Low case + 12% discount rate - capacity expansion in [MW]

10.3.3.2 Costs for capacity expansion

The table and the graph below show the annual CAPEX for the planning period. In contrast to base variant investments, these concentrate on grid connections, import options and TPP candidates in the order of investments.

Period	Invest	Discount_ factor	NPV
	[mioUSD]	[1]	[mioUSD]
2012	0	1.000	0
2013	0	0.893	0
2014	0	0.797	80
2015	0	0.712	0
2016	100	0.636	63.6
2017	170	0.567	96
2018	212	0.507	108
2019	85	0.452	38
2020	340	0.404	137
2021	0	0.361	0
2022	0	0.322	0
2023	212	0.287	61
2024	0	0.257	0
2025	0	0.229	0
2026	0	0.205	0
2027	1525	0.183	279
2028	0	0.163	0
2029	1360	0.146	198
2030	0	0.130	0
2031	0	0.116	0
2032	0	0.104	0
Sum	**4004**		**991**

Table 10.3.3-2 Low case + 12% discount rate - Costs for capacity expansion in [m USD]

10.3.3.3 Unserved demand

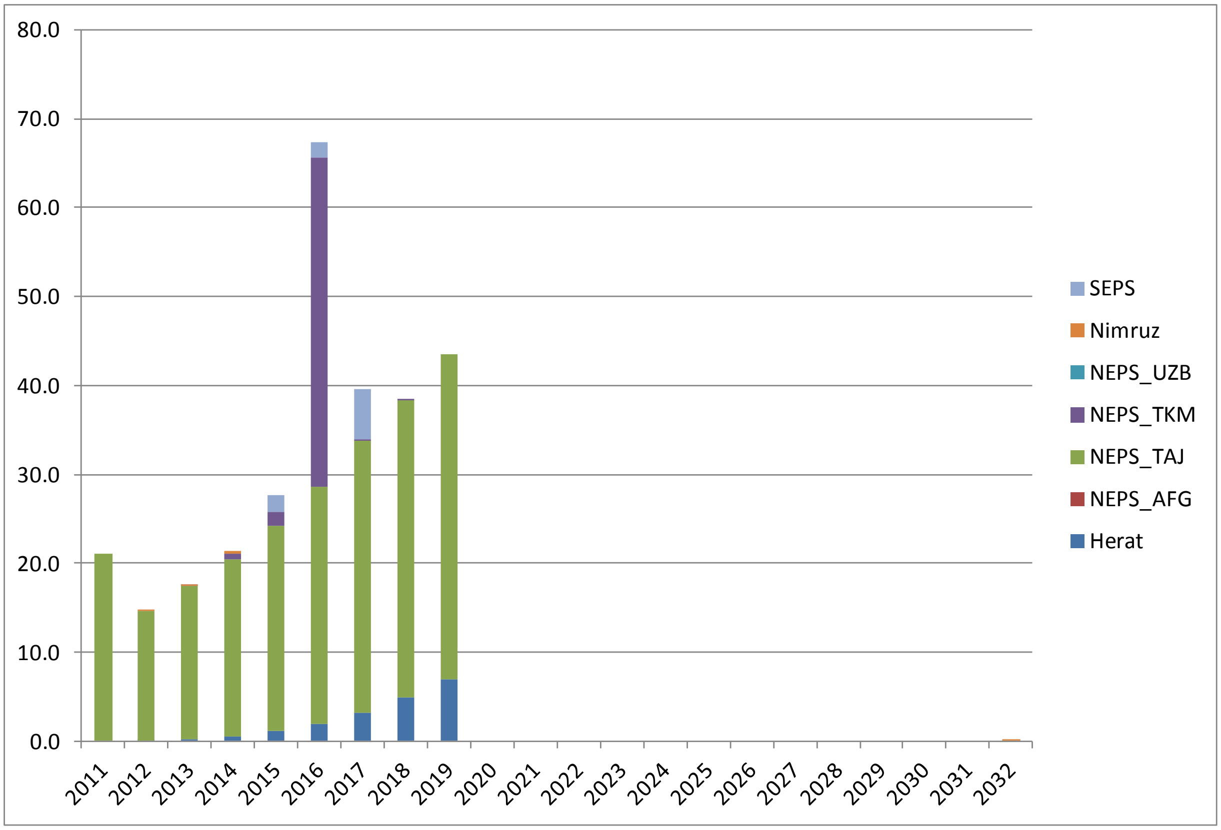


Figure 10.3.3-2: Low case + 12% discount rate - unserved demand in [MW avg]

The above graph shows unserved demand for low case demand and a 12% discount rate. The unserved demand increases up to 2019. This unserved demand is due to structural reasons. The unserved demand in NEPS TAJ up to 2019 results in part from simplifications in the model. Imports from TAJ for various grid islands are generally restricted to summer. The actual system may operate differently, but the simplification does not influence the capacity expansion plan. The start of operation of grid connections is in 2020.

10.4 Risk and Sensitivity Analysis

10.4.1 Variation of demand

High demand forces faster expansion and low demand results in slower expansion. Capacity expansions of coal fired power plants (Bamyan TPP) are assumed to be an external decision.

Basic configuration including

- NEPS 2_SEPS_conn,
- import from TKM and
- Sheberghan TPP

are robust decisions in all variants. Capacity operates early and is expanded in all variants to maximal capacity:

- NEPS 2_SEPS_conn: 300 MW, full operation starts between 2022 and 2027
- Sheberghan TPP: 400 MW, full operation starts between 2020 and 2028
- import lines from TKM to NEPS UZB: 2*500 MW, full operation starts between 2020 and 2023.

Other components depend on demand having a robust expansion order in most variants:

- Kunar B HPP: 300 MW, between 2022 and 2027
- Kunar A HPP: 759 MW, depends on high demand load
- Kajaki addition HPP: 100 MW, depends on high demand load in SEPS / Nimruz.

For variants with high demand all candidates are used. Future investigations of additional alternative options may improve system behavior in these cases towards the end of the planning period.

10.4.2 Variation of discount rates

The discount rate has less influence on the basic configuration:

- NEPS 2_SEPS_conn
- import from TKM
- Sheberghan TPP.

There is a higher influence on build decisions for HPP. A higher discount rate forces later builds and in some cases prevents HPP expansion. A lower discount rate often allows earlier or additional construction of HPP capacity than in variants with a 12% discount rate. This may be explained by high cost differences between different types of power plants.

10.4.3 Sensitivity analysis – price escalations

Due to the high differences between the cost coefficients of different power plants types, we expect a relatively low impact of escalation factors. The same power plants are affected in a comparable way by escalation factors.

Escalation factors are relevant for competition of domestic generation against imported electricity generated with the same type of power plant.

10.4.4 Sensitivity analysis – TAPI

Especially for variants based on base case or high case demand, additional gas-fired power plants in the SEPS region that are built instead of HPP candidates possess clear advantages for the calculated variants. The advantage results from better load behavior because HPP decisions are driven by winter peak requirements with an HPP capacity utilization factor of between 20% and 30%. The required decisions will be taken towards the end of the planning period, thus allowing for future adjustment of the base variant with less uncertainty for TAPI decisions and for demand towards end of the planning period.

10.4.5 Sensitivity – coal-fired power plants (Bamyan, Haji-Gag, etc.)

According to the provided information, we assumed that coal based electricity generation depends on external decisions taken in conjunction with the development of copper or ore mines. As a result of the detailed discussion of coal-fired power plants in previous chapters, we assume the start of production of the first coal-fired power plant will be towards the end of the planning period.
There is no influence during the first years of the planning period, i.e. up to 2025, but will become significant towards the end of the planning period. We propose specifying future decision points for decisions that are to be made towards the end of this period. This will allow flexible adaption of these decisions in the future when better knowledge of external conditions becomes available with lesser uncertainties.

10.4.6 Sensitivity – import load

The investigated options show high dependencies of the electricity system in Afghanistan on energy imports, but because these are comparable for all variants, the sensitivity is low. Even small reductions of external dependencies will lead to a high increase of the overall costs.

Coinciding annual minimums of hydro generation and annual peaking of demand cause – together with significant shares of hydro based electricity generation – a reduced load of the overall system. The optimizations tend to favor thermal based electricity generation.

Reduced loading for thermal power plants may affect domestic thermal power plants or thermal power plants in TKM and UZB used for electricity import to Afghanistan. Reduced loading of domestic TPP results in higher direct costs, while reduced loading for import lines and TPPs in TKM and UZB results in higher import tariffs.

We expect similar fundamental cost structures for gas based electricity generation in Afghanistan, TKM and UZB. Assuming fair contracts for electricity imports, load shifting of TPP generation between Afghanistan, TKM and UZB causes comparable general costs and should result in similar overall costs for Afghanistan. Options for achieving higher load tend to reduce overall costs for capacity expansion:

- TAPI based gas power plants to substitute HPP capacity
- additional exports to PAK
- efficiency improvements, e.g. demand management
- annual load shifting, e.g. enhanced annual hydro storages
- additional TPP based imports, e.g. from TKM to replace HPP based generation.

The differing time characteristics for HPP generation and the demand curves result in a reduced load for the overall system. In our expectation, this will lead to higher overall costs inherent in the system. Assuming fair import contracts with appropriate import tariffs, the shares of load between external and domestic generation should not affect the overall costs.

Apart from a general discussion of costs, lower loading of domestic gas-fired power plants may be used for extended capacity expansion of these power plants. Restrictions result from the available resources and may be analyzed together with an intensive investigation of gas resources around Sheberghan.

10.4.7 Sensitivity – import prices

The investigated options reveal high dependencies of the electricity system in Afghanistan on energy imports. The sensitivity in relation to capacity planning is low because the dependencies are comparable for all variants. Long-term contracts will reduce short-term price risks. Additional export options to PAK will tend to increase domestic generation and will reduce risks due to the symmetrical dependencies of TKM and Afghanistan.

10.4.8 Sensitivity – CAPEX

There are large differences between CAPEX and OPEX for:

- import and grid expansion
- thermal power plants
- hydro power plants.

Due to the given projected demand, these differences result in a low sensitivity to basic capacity decisions. For the same types of power plants, such as HPP, we expect comparable uncertainty of CAPEX.

10.4.9 Sensitivity – emissions

The proposed base variant has a low share of coal and diesel based generation. Additional hydro power plants give rise to a significantly lower load of the overall system and higher costs.

It may be possible to sell carbon credits from Certified Emission Reductions (CER) issued under the Clean Development Mechanism (CDM), provided that the projects are eligible under the CDM. To be eligible, it must be proven that the implementation of specific projects leads to savings in CO_2 emissions.

Taking carbon credits into account will reduce the overall costs, but high differences of generation from gas, hydro, coal and diesel result in low sensitivities for capacity expansion decisions. The calculated schedule may change and can be adapted with near term decisions.

10.4.10 Sensitivity – political instability

Political stability is a major factor for Afghanistan where the planned withdrawal of foreign troops in 2014 gives rise to considerable uncertainties. It is difficult to quantify the impact, but most probably political instability will result in cost increases and delays which are also associated with cost increases.

In general, variants with higher discount rates will reduce sensitivity to political instability, but will also preclude some capital intensive but sustainable investments. During the first years of the planning period up to 2021, there is a low sensitivity and we observe similar behavior and similar impacts for all variants. The variation of discount rates exerts an influence towards the end of the planning period, especially for capacity expansion of hydro power plants.

10.4.11 Valuation of unserved demand

We assume high prices for unserved demand to force its minimization. Significantly lower prices may indicate more extensive demand management and better capacity utilization of the overall system, and may avoid high capacity costs to satisfy infrequent peak load situations.

The disadvantage of lower prices for unserved demand is that it may result in a higher share of unserved demand and in a less reliable energy infrastructure.

10.4.12 Seasonally dependent start of production

For capacity expansion planning we have assumed new power plants and import options starting at the beginning of the planning periods, i.e. at the start of years. In our expectation, the reality for all projects is that they will tend to start operation in autumn, that is around the beginning of October. This will improve the calculated solutions as it is the capacity requirements of winter that force the capacity expansion. The capacity constraints of the overall system arise in winter and there are sufficient reserves during summer.

10.5 Optimistic time schedule for hydro and coal based electricity generation

10.5.1 Variant - optimistic hydro and coal

This variant is based on the demand base case and a discount rate of 12%.
We assumed in this variant 400 MW electricity generation of the **Bamyan coal power plant** starting production in 2020. The load of 200 MW electricity of the corresponding mine is assumed to start in **2020**. The base variant assumes for both 2027. The decision for the coal power plant is taken externally in correspondence with the decision for the mine exploration. The model includes this constraint as fixed input.

We assumed, that the **Kajaki_Addition Hydro Power Plant** with a capacity of 100 MW_el and the Surobi Hydro Power Plant with a capacity of 180 MW may start operation in **2020.** The base variant assumes 2022 for both hydro power plants.

10.5.1.1 Capacity expansion planning

The table and graph below show capacity expansion planning for the variant optimistic time schedule for hydro and coal based electricty generation.

Until 2019 there are no changes versus the base variant. In 2020 the Bamyan coal fired power plant, the Kajaki_Addition hydro power plant and Surobi hydro power plant starts operation.

The second stage of the import line from TKM starts operation in 2022. It is required, the capacity size of 500 MW is mandatory. In comparison to the base variant, construction of other hydro power plants is delayed. The construction sequences of Kunar_A and Kunar_B changes. Kunar_A starts operation in 2027 and Kunar_B in 2031. Late construction of Kuna_B is caused by integer effects of the unit size.

	NEPS_2_SEPS_conn	Sheberghan_TPP_el	TKM_2_NEPS_UZB_import	Bamyan_TPP_el	Kajaki_Addition_HPP	Surobi_HPP	TKM_2_NEPS_UZB_add_import	Kunar_A_HPP	Olambagh_HPP	Kunar_B_HPP	Kama_HPP	Baghdara_HPP	Gulbahar_HPP	Kilagai_HPP	Kukcha_HPP
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	150	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	150	150	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	150	200	300	0	0	0	0	0	0	0	0	0	0	0	0
2019	150	200	300	0	0	0	0	0	0	0	0	0	0	0	0
2020	150	400	500	400	100	180	0	0	0	0	0	0	0	0	0
2021	150	400	500	400	100	180	0	0	0	0	0	0	0	0	0
2022	150	400	500	400	100	180	500	0	0	0	0	0	0	0	0
2023	150	400	500	400	100	180	500	0	0	0	0	0	0	0	0
2024	150	400	500	400	100	180	500	0	0	0	0	0	0	0	0
2025	300	400	500	400	100	180	500	0	0	0	0	0	0	0	0
2026	300	400	500	400	100	180	500	0	0	0	0	0	0	0	0
2027	300	400	500	400	100	180	500	789	0	0	0	0	0	0	0
2028	300	400	500	400	100	180	500	789	0	0	0	0	0	0	0
2029	300	400	500	1200	100	180	500	789	90	0	0	0	0	0	0
2030	300	400	500	1200	100	180	500	789	90	0	0	0	0	0	0
2031	300	400	500	1200	100	180	500	789	90	300	0	0	0	0	0
2032	300	400	500	1200	100	180	500	789	90	300	45	0	0	0	0

Table 10.5.1-1: Optimistic hydro and coal - capacity expansion in [MW]

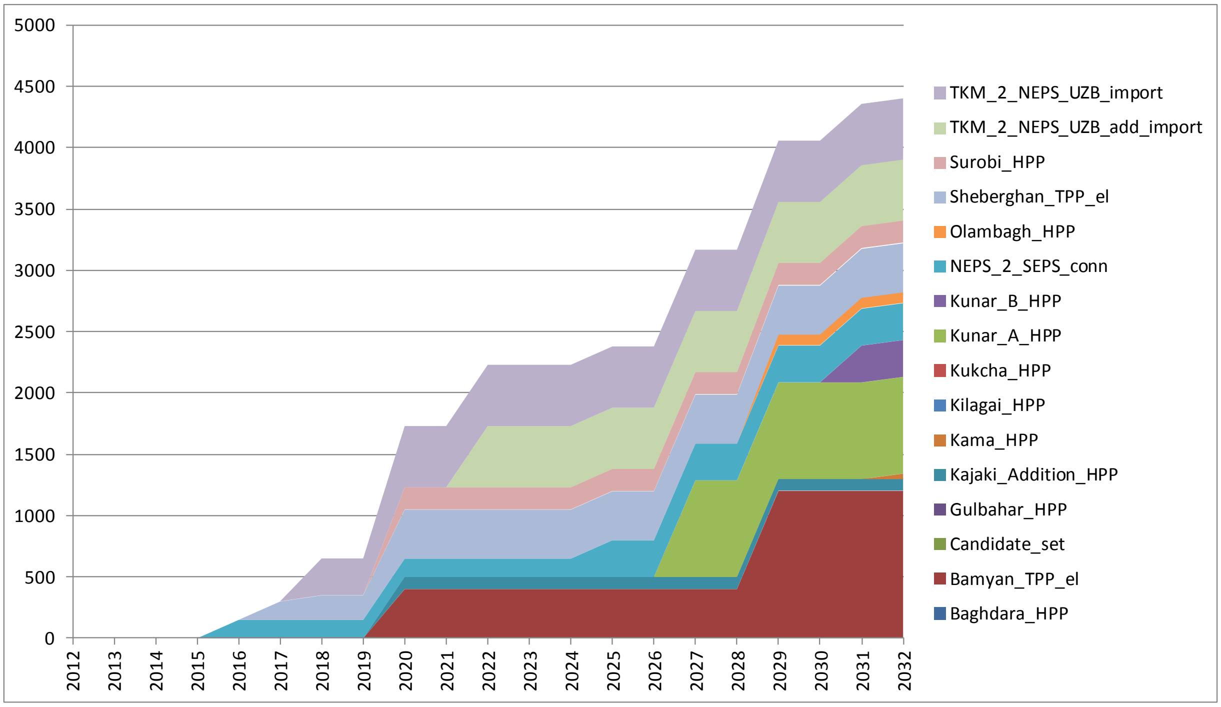


Figure 10.5.1-1: Optimistic hydro and coal - capacity expansion in [MW]

10.5.1.2 Costs of the projects

The table below shows the investment cost for the variant. The total invest is comparable to the base variant, but the Net Present Value (NPV) is significant lower due to late construction of large hydro power plants. This causes a higher residual value at the end of the planning period.

Period	Invest	Discount factor	NPV
	[mioUSD]	[1]	[mioUSD]
2012	0	1.000	0
2013	0	0.893	0
2014	0	0.797	0
2015	0	0.712	0
2016	100	0.636	64
2017	255	0.567	145
2018	212	0.507	108
2019	0	0.452	0
2020	2105	0.404	850
2021	0	0.361	0
2022	212	0.322	68
2023	0	0.287	0
2024	0	0.257	0
2025	100	0.229	23
2026	0	0.205	0
2027	2200	0.183	402
2028	0	0.163	0
2029	1800	0.146	262
2030	0	0.130	0
2031	660	0.116	77
2032	198	0.104	21
Sum	**7842**		**2018**

Table 10.5.1-2: Optimistic hydro and coal - costs for capacity expansion in [mioUSD]

10.5.1.3 Annual electricity generation

The table below presents the annual electricity generation [GWh]. The electricity generation is shown

- per power plant type - Hydro based (HPP) and thermal based (TPP) electricity generation
- domestic generation versus imported electricity

The table shows corresponding shares of TPP / HPP generation and of domestic / imported electricity.

Annual electricity generation	HPP domestic	TPP domestic	HPP import	TPP import	Total electricity generation	HPP share	TPP share	Domestic share	Import share
	[GWh]	[GWh]	[GWh]	[GWh]	[GWh]	[%]	[%]	[%]	[%]
2012	1328	469	97	1988	3881	37	63	46	54
2013	1368	571	118	2280	4337	34	66	45	55
2014	1404	698	141	2583	4827	32	68	44	56
2015	1439	836	168	2893	5335	30	70	43	57
2016	1459	780	200	3155	5594	30	70	40	60
2017	1475	1420	236	3488	6620	26	74	44	56
2018	1485	1384	266	4163	7297	24	76	39	61
2019	1489	1507	298	4540	7833	23	77	38	62
2020	2875	3778	1028	3159	10839	36	64	61	39
2021	2875	3929	1168	3415	11388	36	64	60	40
2022	2875	3568	1293	4356	12091	34	66	53	47
2023	2875	3682	1308	4934	12799	33	67	51	49
2024	2875	3753	1312	5532	13472	31	69	49	51
2025	2875	3865	1316	6134	14191	30	70	47	53
2026	2875	4028	1318	6688	14909	28	72	46	54
2027	7511	3509	343	4323	15685	50	50	70	30
2028	7543	3861	513	4575	16492	49	51	69	31
2029	8090	5397	1246	6110	20842	45	55	65	35
2030	8090	5756	1269	6610	21725	43	57	64	36
2031	9544	5869	1093	6143	22649	47	53	68	32
2032	9771	6260	1142	6444	23617	46	54	68	32

Table 10.5.1-3: Optimistic hydro and coal - electricity generation in [GWh]

10.5.1.4 System costs and average electricity cost

The table below shows system costs and average annual electricity costs. The weighted average electricity cost for the complete planning period is estimated to 55.7 USD/MWh. The overall costs for electricity are significant higher as in the base variant between 2020 and 2026. This results in significant higher overall costs and higher average electricity costs.

Annual electricity generation	Total electricity generation	Generation capacity cost	OPEX domestic generation	Coal	Diesel	Natural_Gas	Electricity import	Annual system cost	Average annual cost (including generation capacity cost)	Average annual cost (excluding generation capacity cost)
	[GWh]	[mioUSD]	[mioUSD]	[mioUSD]	[mioUSD]	[mioUSD]	[mioUSD]	[mioUSD]	[USD/MWh]	[USD/MWh]
2012	3881	0.0	17	0	30	10	86	144	37.0	37.0
2013	4337	0.0	19	0	49	11	101	179	41.3	41.3
2014	4827	0.0	20	0	80	11	116	227	47.1	47.1
2015	5335	0.0	22	0	114	11	132	279	52.2	52.2
2016	5594	0.0	21	0	102	11	144	278	49.8	49.8
2017	6620	28.8	27	0	144	22	162	384	58.1	53.7
2018	7297	52.1	27	0	25	31	200	335	45.9	38.8
2019	7833	52.1	28	0	43	32	220	376	48.0	41.4
2020	10839	284.1	62	17	0	78	196	638	58.8	32.6
2021	11388	284.1	65	24	7	79	214	673	59.1	34.1
2022	12091	306.8	56	1	3	80	264	710	58.8	33.4
2023	12799	306.8	59	4	5	81	294	751	58.6	34.7
2024	13472	306.8	60	8	9	81	326	791	58.7	35.9
2025	14191	306.8	63	16	2	81	357	826	58.2	36.6
2026	14909	306.8	66	22	17	81	386	879	59.0	38.4
2027	15685	543.3	78	16	3	72	239	950	60.6	26.0
2028	16492	543.3	84	23	22	75	258	1006	61.0	28.1
2029	20842	744.3	125	105	6	81	363	1423	68.3	32.6
2030	21725	744.3	133	125	8	81	390	1482	68.2	33.9
2031	22649	815.3	142	132	16	80	360	1545	68.2	32.2
2032	23617	836.5	151	148	44	80	377	1638	69.4	33.9

Figure 10.5.1-2: Optimistic hydro and coal - System costs and average electricity costs

10.5.1.5 Dispatching

The two graphs below present the dispatching of the thermal based generation including electricity imports based on thermal generation in 2020 and in 2025. The power plants in Sheberghan and Balk have cheaper or comparable marginal costs than thermal based electricity imports. The coal based electricity generation in Bamyan has high marginal costs, usage is restricted to peak load in winter. This results in an extremely low load factor for the Bamyan power plant. The investment for the Bamyan coal fired power plant with a capacity of 400 MW in 2020 is - under given base conditions - not reasonable.

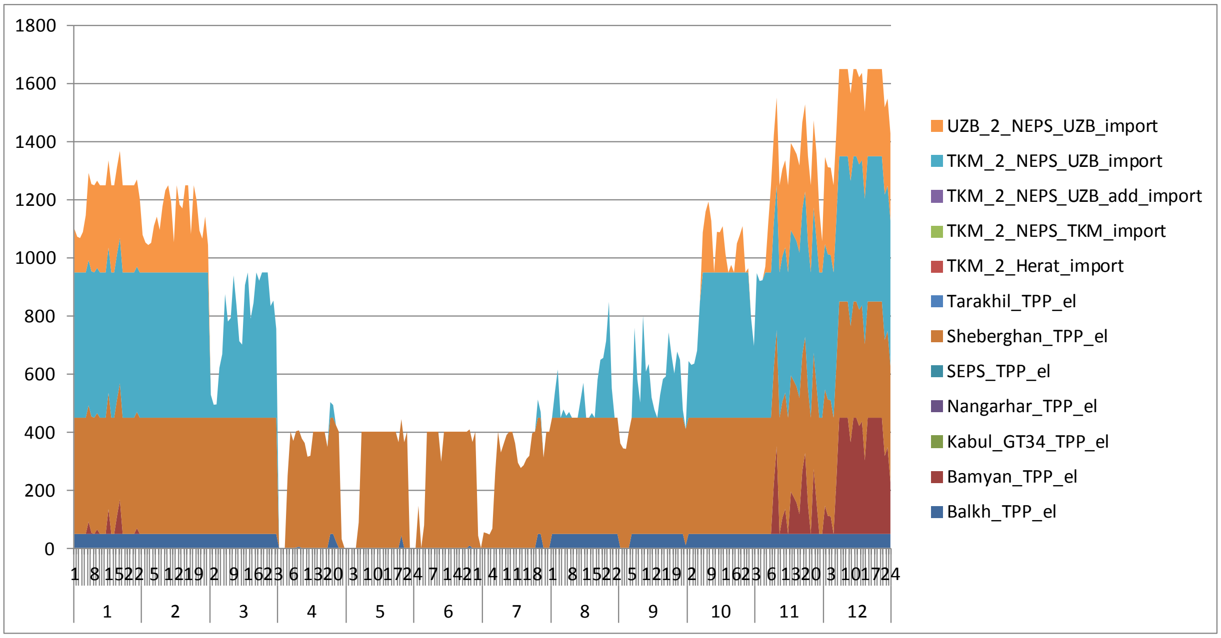


Figure 10.5.1-3: Optimistic hydro and coal - TPP schedule 2020 in [MW]

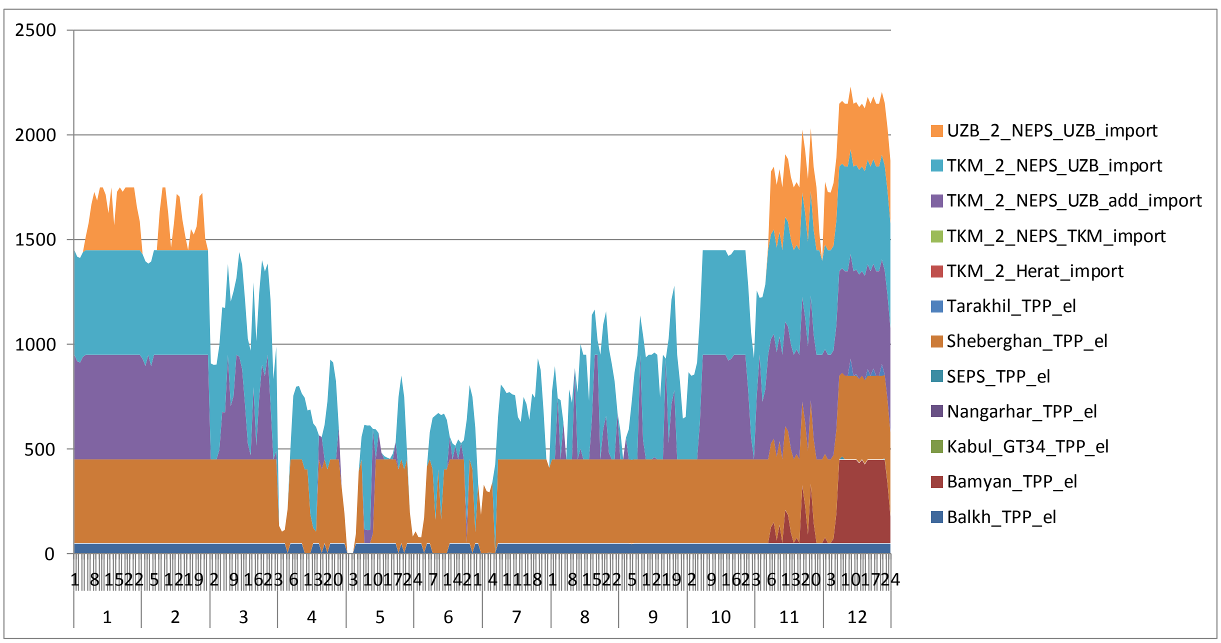


Figure 10.5.1-4: Optimistic hydro and coal - TPP schedule 2025 in [MW]

10.5.1.6 Unserved demand

In comparison to the base variant we do not have changes in the capacity expansion until 2019. The unserved demand - mainly until 2019 - is comparable to the base variant.

10.5.1.7 Load variation for coal based electricity generation at Bamyan

Motivated by the worse load factor of the Bamyan power plant we analyzed additional variants for the Bamyan power plant:

- Minimum of zero full load operating hour per year for the Bamyan_TPP
  => Variant Bamyan_2020_0
- Minimum of 50% annual load resulting in 3000 full load operating hour per year for the Bamyan_TPP
  => Variant Bamyan_2020_050
- Minimum of 100% annual load resulting in 6000 full load operating hour per year for the Bamyan_TPP
  => Variant Bamyan_2020_100

All variants include a mandatory production start in 2020 for the Bamyan coal fired power plant (400 MW), the Surobi hydro power plant (180 MW) and the Kajaki_Addition hydro power plant (100 MW).

A comparison of electricity generation, of domestic shares for the three load variations and of resulting costs is given in the tables below.

	Annual system cost				Difference to basevariant		
Annual system cost	Base variant	Bamyan_2020_0	Bamyan_2020_50	Bamyan_2020_100	Bamyan_2020_0	Bamyan_2020_50	Bamyan_2020_100
	[mioUSD]	[mioUSD]	[mioUSD]	[mioUSD]	[mioUSD]	[mioUSD]	[mioUSD]
2012	144	144	144	144	0	0	0
2013	179	179	179	179	0	0	0
2014	227	227	227	227	0	0	0
2015	279	279	279	279	0	0	0
2016	278	278	278	278	0	0	0
2017	384	384	384	384	0	0	0
2018	335	335	335	335	0	0	0
2019	376	376	376	376	0	0	0
2020	522	638	662	710	116	141	189
2021	554	673	694	740	119	140	186
2022	594	710	740	777	116	146	183
2023	640	751	783	816	110	143	176
2024	724	791	821	855	66	97	131
2025	765	826	852	889	61	87	124
2026	827	879	902	938	52	75	111
2027	925	950	977	1026	26	52	102
2028	975	1006	1028	1076	31	53	102
2029	1389	1423	1475	1608	35	86	219
2030	1445	1482	1522	1647	37	78	202
2031	1514	1545	1581	1702	30	67	188
2032	1613	1638	1666	1795	26	54	182

Figure 10.5.1-5: Optimistic hydro and coal - Variant comparison of annual system costs

The table above presents a comparison of the base variant and the three load variations of the optimistic hydro and coal variant. The overall annual system costs are given on the left side of the table. They include annual generation capacity costs, opex for the projected generation assets and fuel costs. On the right side of the table the difference costs of the optimistic hydro and coal variants oin relation to the base variant are given. Equal costs are visualized in dark green colour, additional costs until 40 [mioUSD/a] are visualized in light green colours and high additional costs are visualized in orange and red colors. Due to high costs of coal based electricity generation the economic disadvantage is increasing with additional constraints to insure better load factors of the Bamyan_TPP. The additional costs for the variant Bamyan_2020_0 from 2026 to 2032 are caused from higher costs of the Surobi_HPP in relation to HPP generation used in the base variant. The table below presents weighted average electricity generation costs for the complete planning period. The optimistic HPP and coal variants will increase average electricity generation costs significant.

Electricity cost	Base variant	Bamyan_2020_0	Bamyan_2020_50	Bamyan_2020_100
	[USD/MWh]	[USD/MWh]	[USD/MWh]	[USD/MWh]
Weighted average electricity costs over the planning period including generation capacity costs	52.5	55.7	56.8	59.1

Figure 10.5.1-6: Optimistic hydro and coal - Variant comparison of weighted average electricity costs

	Base variant						Bamyan_2020_100						Diff to base variant		
Annual electricity generation	HPP domestic	TPP domestic	HPP import	TPP import	HPP share	Domestic share	HPP domestic	TPP domestic	HPP import	TPP import	HPP share	Domestic share	Bamyan_100 Additonal domestic share	Bamyan_50 Additonal domestic share	Bamyan_0 Additonal domestic share
	[GWh]	[GWh]	[GWh]	[GWh]	[%]	[%]	[GWh]	[GWh]	[GWh]	[GWh]	[%]	[%]	[%]	[%]	[%]
2012	1328	469	97	1988	37	46	1328	469	97	1988	36.7	46.3	0	0	0
2013	1368	571	118	2280	34	45	1368	571	118	2280	34.3	44.7	0	0	0
2014	1404	698	141	2583	32	44	1404	698	141	2583	32.0	43.6	0	0	0
2015	1439	836	168	2893	30	43	1439	836	168	2893	30.1	42.6	0	0	0
2016	1459	780	200	3155	30	40	1459	780	200	3155	29.7	40.0	0	0	0
2017	1475	1420	236	3488	26	44	1475	1420	236	3488	25.9	43.7	0	0	0
2018	1485	1384	266	4163	24	39	1485	1384	266	4163	24.0	39.3	0	0	0
2019	1489	1507	298	4540	23	38	1489	1507	298	4540	22.8	38.2	0	0	0
2020	1491	3196	1318	4835	26	43	2875	4366	1252	2346	38.1	66.8	24	26	18
2021	1491	3610	1318	4969	25	45	2875	4384	1273	2856	36.4	63.7	19	22	15
2022	2976	3556	1238	4321	35	54	2875	4394	1294	3528	34.5	60.1	6	10	-1
2023	2976	3672	1303	4847	33	52	2875	4406	1308	4210	32.7	56.9	5	8	-1
2024	7412	2550	0	3510	55	74	2875	4822	1312	4462	31.1	57.1	-17	-17	-25
2025	7481	2813	34	3862	53	73	2875	5991	1316	4008	29.5	62.5	-10	-19	-25
2026	7943	2883	52	4031	54	73	2875	6053	1318	4663	28.1	59.9	-13	-21	-26
2027	8020	3275	205	4185	52	72	7511	5332	0	2842	47.9	81.9	10	4	-2
2028	8061	3611	355	4464	51	71	7543	5733	2	3215	45.7	80.5	10	3	-2
2029	8673	5265	1111	5793	47	67	8090	10563	108	2081	39.3	89.5	23	7	-2
2030	8677	5641	1217	6190	46	66	8090	10602	581	2452	39.9	86.0	20	5	-2
2031	8682	6046	1244	6677	44	65	8090	10710	1046	2802	40.3	83.0	18	9	3
2032	9630	6247	1196	6545	46	67	9771	10735	223	2888	42.3	86.8	20	5	1

Figure 10.5.1-7: Optimistic hydro and coal - Variant comparison of electricity generation and domestic share

The table above presents energy generation of the Bamyan_2020_100 variant and a detailed comparison with the base variant. On the right side the increase (decrease) of the domestic share in relation to the base variant is given for the described optimistic hydro and coal variants. Between 2020 and 2023 the domestic share increases in all optimistic hydro and coal variants. It is about 20% higher than the domestic share in the base variant. Between 2024 and 2026 the domestic share is between 10 and 25 % lower than the domestic share of the base variant. In the optimistic hydro and coal variants the hydro and coal power plants starting in 2020 cause a time shift for the expansion of large domestic (hydro) capacities. Small differences in the domestic share of the Bamyan_2020_0 and Bamyan_2020_50 variant in relation to the base variant between 2027 and 2032 result from different hydro generation configurations.

Bamyan_2020_100								**Diff Bamyan_2020_100 - Base variant**						
Annual electricity generation	**Generation capacity cost**	**OPEX domestic generation**	**Coal**	**Diesel**	**Natural_Gas**	**Electricity import**	**Annual system cost**	**Generation capacity cost**	**OPEX domestic generation**	**Coal**	**Diesel**	**Natural_Gas**	**Electricity import**	**Annual system cost**
	[mioUSD]													
2012	0	17	0	30	10	86	144	0	0	0	0	0	0	**0**
2013	0	19	0	49	11	101	179	0	0	0	0	0	0	**0**
2014	0	20	0	80	11	116	227	0	0	0	0	0	0	**0**
2015	0	22	0	114	11	132	279	0	0	0	0	0	0	**0**
2016	0	21	0	102	11	144	278	0	0	0	0	0	0	**0**
2017	29	27	0	144	22	162	384	0	0	0	0	0	0	**0**
2018	52	27	0	25	31	200	335	0	0	0	0	0	0	**0**
2019	52	28	0	43	32	220	376	0	0	0	0	0	0	**0**
2020	246	99	140	23	43	160	710	133	55	140	20	-29	-130	**189**
2021	268	100	140	0	46	185	740	146	53	140	-6	-35	-112	**186**
2022	268	100	140	3	46	220	777	75	48	140	-6	-33	-40	**183**
2023	268	100	140	5	46	256	816	75	46	140	-17	-35	-34	**176**
2024	278	104	140	9	55	269	855	-152	43	140	9	-2	93	**131**
2025	307	114	140	2	81	245	889	-123	51	140	-13	19	49	**124**
2026	307	115	140	17	81	279	938	-155	48	140	-15	19	74	**111**
2027	543	127	140	3	65	148	1026	4	52	126	0	-2	-78	**102**
2028	543	131	140	22	72	168	1076	4	51	119	5	1	-79	**102**
2029	744	251	421	6	74	112	1608	4	130	321	0	-6	-230	**219**
2030	744	251	421	8	75	147	1647	4	121	301	0	-5	-219	**202**
2031	744	253	421	28	76	181	1702	4	114	282	5	-6	-212	**188**
2032	837	260	421	44	75	158	1795	26	112	273	5	-6	-226	**182**

Figure 10.5.1-8: Optimistic hydro and coal - Variant comparison of detailed cost structure

The table above shows the detailed annual cost structure (left side) and the corresponding differences in relation to the base variant (right side). The Bamyan_2020_100 variant causes higher annual costs for fuel (coal) and a higher opex. The savings from a reduced import of electricity can not compensate the higher costs for coal based generation. Between 2020 and 2032 there are higher annual costs ranging from 100 to 200 mio USD/a in relation to the base variant.

10.5.2 Additional analysis of optimistic coal and hydro generation

The results of the previous sub chapter show economic disadvantages of the optimistic coal and hydro variants. A higher domestic share results in high additional costs. Reasons are high costs for capacity expansion and high fuel costs for the Bamyan coal fired power plant.

We analyzed capacity expansion for the optimistic coal and hydro variant, if the optimizer can choose the optimal time schedule for capacity expansion of the Bamyan_TPP (400 MW) between 2020 and 2027, the Kajaki_Addditon_HPP (100 MW) from 2020 and the Surobi_HPP (180 MW) from 2020. Removing the unit constraint for the Bamyan power plant between 2020 and 2027 allows suitable capacity expansion in small steps for the Bamyan power plant. The resulting capacity expansion plan is given in the table below. The Surobi_HPP is not used as in the base variant due to relative high capacity costs. For the Bamyan power plant the optimizer calculates a capacity expansion of 74 MW between 2024 and 2026. Due to the changed expansion of the Bamyan power plant the capacity expansion for the Kajaki_Addition_HPP is calculated in 2028 - two years later as in the base variant.

As a result of these extended analysis of the optimistic hydro and coal variants an additional domestic share of electricity generation results in high additional costs for the overall system. Without additional constraints the cost optimal solution tends towards the base variant. Adjustments to the capacity size of the coal power plants may improve the cost structure of the overall system. We recommend to optimize the capacity size of the coal fired power plants in conjunction with a concretization of the mine projects.

	Baghdara_HPP	Bamyan_TPP_el	Gulbahar_HPP	Kajaki_Addition_HPP	Kama_HPP	Kilagai_HPP	Kukcha_HPP	Kunar_A_HPP	Kunar_B_HPP	NEPS_2_SEPS_conn	Olambagh_HPP	Sheberghan_TPP_el	Surobi_HPP	TKM_2_NEPS_UZB_add_import	TKM_2_NEPS_UZB_import
	[MW]	[MW]	[MW]	[MW]	[MW]	[MW]	[MW]	[MW]	[MW]	[MW]	[MW]	[MW]	**[MW]**	[MW]	[MW]
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	150	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	150	0	150	0	0	0
2018	0	0	0	0	0	0	0	0	0	150	0	200	0	0	300
2019	0	0	0	0	0	0	0	0	0	150	0	200	0	0	300
2020	0	**0**	0	**0**	0	0	0	0	0	150	0	350	**0**	500	500
2021	0	**0**	0	**0**	0	0	0	0	0	150	0	400	**0**	500	500
2022	0	**0**	0	**0**	0	0	0	0	300	150	0	400	0	500	500
2023	0	**0**	0	**0**	0	0	0	0	300	300	0	400	0	500	500
2024	0	**74**	0	**0**	0	0	0	0	300	300	0	400	0	500	500
2025	0	**74**	0	**0**	0	0	0	789	300	300	0	400	0	500	500
2026	0	**74**	0	**0**	0	0	0	789	300	300	0	400	0	500	500
2027	0	400	0	**0**	0	0	0	789	300	300	0	400	0	500	500
2028	0	400	0	100	0	0	0	789	300	300	0	400	0	500	500
2029	0	1200	0	100	0	0	0	789	300	300	90	400	0	500	500
2030	0	1200	0	100	0	0	0	789	300	300	90	400	0	500	500
2031	0	1200	0	100	0	0	0	789	300	300	90	400	0	500	500
2032	210	1200	0	100	0	0	0	789	300	300	90	400	0	500	500

10.5.2.1 Optimistic Hydro and Coal Variant - Conclusion

An additional analysis of a more optimistic schedule for construction of coal and hydro based power plants was performed. The very low load of the Bamyan power plant in the first years shows economic disadvantages of this variant. From an economic point of view the operation of the Bamyan coal fired power plant with 400 MW from 2020 is not recommended. A higher usage will result in high fuel cost and in even higher overall costs.

An extended analysis shows, that even the additional hydro power plants Kajaki_Addition_HPP (100 MW) and Surobi_HPP (180) MW starting operation in 2020 will result in additional costs in comparison to the base variant. Without additional constraints the cost optimum tends towards the base variant and the optimizing system calculates a capacity expansion plan, which is identical to the base variant.

The base variant is cost optimal and robust in relation to the analyzed optimistic hydro and coal variants.

10.6 Recommendation – Roadmap and Robust Strategy

Basic grid configurations and external dependency on the development of the copper and the ore mines have been fixed for the preliminary analysis. The configuration works well and forms, together with the results of the scenario analysis, a robust solution.

The solution for the base variant is robust. Analyzed relevant sensitivities are low with non-problematic behavior. The solution for the first part of the planning period defines a clear and comprehensible capacity expansions plan. It works with slight adaptations for the analyzed variations and sensitivities as well. Our recommendation is to start implementation of the project in Sheberghan and of the import / grid connection projects by 2020. The optimization clearly shows that the proposed expansion is required to satisfy demand as from 2020.

The solution for the second part of the planning period shows higher variations and sensitivities. This seems reasonable due to greater uncertainties and required additional investigations up to the start of the projects. The **Kunar B**, **Kunar A** and **Kajaki_Addition** projects appear to be very robust. Nearly all variants will implement these projects. Exceptions result from very low demand projections and high discount rates, so project development should start with an additional investigation. The projects may be shifted in time, depending on the future adjusted demand projections.

The coal-fired power plants do not have any impact until towards the end of the planning period. Adjustments must be made to the starts of the corresponding projects or due to changes of these. Project development – TPP and mine explorations – must commence with additional investigations. Depending on the results of these investigations and the economic aspects of the mine projects, development of these coal-fired projects may be adjusted. Impacts on the overall energy system of Afghanistan require, in conjunction with the high case demand, additional generation options.

For all other projects, we recommend additional investigations. Project implementation and optional time shifts should be prepared depending on the adjusted demand projections. For these projects, optimal decision points for cost intensive project components should be specified as late as possible, but robust project implementation must be ensured.

In the base case and high case demand projections, alternative generation and import options are highly welcome and will improve the load characteristics and cost effectiveness of the overall system:

- TAPI based gas power plants to replace HPP capacity
- additional exports to PAK
- efficiency improvements, e.g. demand management
- load shifting, e.g. enhanced annual hydro storage
- additional TPP based imports, e.g. from TKM.

These options will complement system design, may take the place of hydro generation and could result in putting back the described hydro projects to the end of the planning period. In general, they will be implemented towards the end of the planning period and the base case variant may be adjusted in line with improved demand projections and changed external conditions.

Electricity generation based on renewables (PV, wind) has just a minor influence on the grid based system due to high hydro share and HPP load characteristics. Renewables are discussed for decentralized systems and specific market segments in a separate chapter.

The variants with base case and high case demand reach their limits in Herat at Nimruz toward the end of the planning period. Due to the high uncertainty, we recommend that decision points be defined and that projects be adjusted in the future depending on demand projections and regional development. An option may include import of electricity from Iran and TKM for individual regions.

An additional analysis of a more optimistic schedule for construction of coal and hydro based power plants was performed. The very low load of the Bamyan power plant in the first years shows economic disadvantages of this variant. From an economic point of view the construction of the Bamyan coal fired power plants until 2020 is not recommended. A higher usage will result in high fuel cost and in even higher overall costs.

The additional variants show, the usage of the hydro power plants Kajaki_Addition_HPP (100 MW) and Surobi_HPP (180) MW beginning in 2020. Implications to the overall system load and implications to the overall system costs are varying in dependence of the demand. The additional HPP's will increase domestic production.

10.6.1 Recommendation – capacity expansion plan

	NEPS_2_SEPS_conn	Sheberghan_TPP_el	TKM_2_NEPS_UZB_import	TKM_2_NEPS_UZB_add_import	Kunar_B_HPP	Kunar_A_HPP	Bamyan_TPP_el	Kajaki_Addition_HPP	Olambagh_HPP	Baghdara_HPP	Gulbahar_HPP	Kama_HPP	Kilagai_HPP	Kukcha_HPP	Surobi_HPP
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	150	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	150	150	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	150	200	300	0	0	0	0	0	0	0	0	0	0	0	0
2019	150	200	300	0	0	0	0	0	0	0	0	0	0	0	0
2020	150	200	500	500	0	0	0	0	0	0	0	0	0	0	0
2021	150	250	500	500	0	0	0	0	0	0	0	0	0	0	0
2022	150	350	500	500	0	0	0	0	0	0	0	0	0	0	0
2023	300	400	500	500	0	0	0	0	0	0	0	0	0	0	0
2024	300	400	500	500	300	0	0	0	0	0	0	0	0	0	0
2025	300	400	500	500	300	0	0	0	0	0	0	0	0	0	0
2026	300	400	500	500	300	789	0	0	0	0	0	0	0	0	0
2027	300	400	500	500	300	789	400	0	0	0	0	0	0	0	0
2028	300	400	500	500	300	789	400	100	0	0	0	0	0	0	0
2029	300	400	500	500	300	789	1200	100	90	0	0	0	0	0	0
2030	300	400	500	500	300	789	1200	100	90	0	0	0	0	0	0
2031	300	400	500	500	300	789	1200	100	90	0	0	0	0	0	0
2032	300	400	500	500	300	789	1200	100	90	210	0	0	0	0	0

Table 10.6.1-1: Recommendation - robust capacity expansion in [MW]

10.6.2 Recommendation – costs for capacity expansion

Period	Invest	Discount_ factor	NPV
	[mioUSD]	[1]	[mioUSD]
2012	0	1.000	0
2013	0	0.893	0
2014	0	0.797	0
2015	0	0.712	0
2016	100	0.636	63.6
2017	255	0.567	145
2018	212	0.507	108
2019	0	0.452	0
2020	297	0.404	120
2021	85	0.361	31
2022	170	0.322	55
2023	185	0.287	53
2024	660	0.257	169
2025	0	0.229	0
2026	2200	0.205	450
2027	680	0.183	124
2028	300	0.163	49
2029	1800	0.146	262
2030	0	0.130	0
2031	0	0.116	0
2032	660	0.104	68
Sum	**7604**		**1700**

Table 10.6.2-1: Recommendation, capacity expansion costs for robust base variant

11. Power System Analysis

It is the aim of the network study to iteratively optimize the planned high voltage power systems, until it finally comprises a realistic network expansion plan at stable and reliable operation modes. It is however impossible to design a system resilient to all varieties of long-term development options. The shown results therefore are to be seen as basis for decisions to be made in the short and mid-term perspective. In the longer run the optimization process has to be adjusted to the future expansion process.

The network study consists of two steps:

1. Power flow study presented in chapter 11.2,
2. Dynamic study presented in chapter 11.3.

The following will present the modeling, the results of load flow and dynamic studies are presented afterwards.

11.1 Modeling

11.1.1 Software used

The Afghan electric power system is modeled using PSSE® software. All power flow, short circuit and system stability calculations will be performed with the PSSE® software. Results are available as Microsoft Excel 2007 export and as single line diagrams in pdf format.

11.1.2 Transmission elements

The network elements modeled include all assets at 110 kV level and above. The loads at 20 kV buses are connected via step down transformers. Generators are modeled likewise.

Values for transmission lines are subject to the conductor / tower configuration and length. Figures for line lengths where gathered in the inception phase. Proposed lines receive lengths derived from a desktop study scaled by an adjustment factor reflecting geographic influences on the line routing. Requirements on transmission capacities and according line voltages result in conductor and tower configurations. Datasheets on conductor material is the basis for determining the carrying capacity. It is however important to note that all ratings are derived from laboratory values. The proposals on line configuration tend to be conservative as lower ambient temperatures in Afghanistan lead to higher capacities. Only a detailed investigation in the course of a project specification can however provide reliable line configurations.

11.1.3 Generators

The machines of each power plant are modeled explicitly if possible. This applies to all power plants currently in service. Projected generation projects however must reduce to a simple model of a generator with implicitly (hidden) step up transformers.

11.1.4 Loads

The load values base on the recorded loads and the load forecast presented in Chapter 3. Table 5.3.5-1 in Chapter 5 lists the allocation of substations to Afghan provinces. The models' load input values are load values of corresponding provinces equally apportioned to the substations.

The network calculation bases on a model of the power systems physics. It calculates line and transformer losses in MW. Transmission losses however, are already included in the load forecast figures (see Chapter 3.3). Hence the load input must be reduced by the losses produced in the power transmission system. Hence they calculate as:

$$P = P_{fc} \cdot (1 - \frac{ls}{100\%})$$

Where:

P	… Active Power in MW
P_{fc}	… Forecasted active power in MW
ls	… Technical transmission losses in %; ls = 10 %.

The relative loss is set to 10 % irrespective of development stages (and time horizon) for it is meant to compensate transmission loss generated on high voltage level only. That loss will not exceed 10%. Any further losses (e.g. distribution) remain within P.

To bring the network model closer to reality a load conversion function initially performed in USAID studies is carried out. All loads are modeled as follows:

- Constant Current: 20 %
- Constant admittance: 50 %
- Constant active power: 30%

Details on dynamic modeling are given in section 11.3

11.2 Results of power flow simulations

Power flow simulations have been performed for the following expansion stages:

- Stage A 2015: the planned power system state in 2015,
- Stage B 2020: the planned power system state in 2020,
- Stage C 2025: the planned power system state in 2025,
- Stage D 2032: the planned power system state in 2032.

The results presented here are a selection of the simulation results. They shall provide a comprehensive picture of the network characteristics, features and operation constraints.

The studies performed base on peak load occurring at wintertime. All calculations are therefore carried out under following conditions:

- Winter time peak load reduced by technical transmission losses are applied to all load models,
- Load power factor cos φ = 0.95,
- In winter times thermal power plants are favored over hydropower plants due to their then-peaking efficiency, caused by low ambient temperatures,
- Reduction of output power of run of river hydropower plants by 75 %,

Run of river hydro power plants are:

- Salma HPP,
- Olambagh HPP.

Both sites are relevant only for Stage D 2032.

11.2.1 Stage A: the planned power system state in 2015

Due to the high share of imports from unsynchronized systems the afghan power system remains sectionalized. The system separates in six unsynchronized islands namely:

1. Uzbekistan - Kabul (UZB-Kab),
2. Turkmenistan - Kabul - Badakshan (TKM-Mai-Kab 2015),
3. Kabul - Kandahar (Kabul-Kandahar),
4. Turkmenistan - Herat (TKM-Herat),
5. Iran - Herat (IRA-Herat),
6. Mazar-e-Sharif TPP island (Mazar-e-Sharif TPP).

The according single line diagram is given in **Annex 11.2.1-1** for summer operation and **Annex 11.2.1-2** for winter operation. **Annex 11.2.1-3** provides the topologic allocation. A list of all compensation equipment and costs is provided in Table 11.2.1-3 on page 11-13.

11.2.1.1 Network simulation conditions

Major transmission projects

In total 25 new lines are proposed in advance of 2012. Top priority projects are

- 500 kV Turkmenistan Afghanistan interconnector, currently under development by ADB,
- 220 kV DC line from Andkhoy via Sheberghan to Mazar-e-Sharif,
- 220 kV SC line from Sarobi HPP to Arghandi,
- 220 kV DC line from Arghandi to Kandahar via Sayd Abad, Ghazni and Gelan (NEPS-SEPS interconnector).

Load scenarios

The required power at summer is delivered by Turkmenistan, Uzbekistan, Iran and Tajikistan. For Tajikistan is only able to provide seasonal hydroelectric power its 300 MW may then be used to feed the load centers at Kunduz, Takhar, Badakshan, Baghlan, Balkh and Samangan (Pol-e-Chomri operated at split bus). Check Annex 11.1.2-1 for according grid configuration SLD.

In winter operation, due to the lack of tajik hydroelectric power, Turkmenistan will feed loads at Kunduz, Takhar and Badakshan. In this operation scenario the bus voltages are most critical as the power will be drawn from the Afghan-Turkmen border at Aqeena. The long distance results in higher line impedances (compared to the summer time operation scenario) and thus higher voltage drop.

The winter operation mode was simulated and will be presented hereafter.

It is assumed that the substations of Bagram and Dehsabz South share the load expected for the Kabul New City project. Their total load sums up to 110 MW.

11.2.1.2 Results of power flow calculations

Table 11.2.1-1 sums up the fundamental outcomes for generation and demand of the load flow calculations at the winter operation scenario.
The load flow calculation results for development Stage A for winter operation scenario are given within the single line diagram in **Annex 11.2.1-4**.

95 % of the afghan winter time peak load will be covered by domestic generation and imports. Load shedding is not necessary. 5% of power demand however resides in remote areas and cannot be energized by the transmission grid. The simulated transmission loss on high voltage level is 10 %.

Power generation			
Power system segment		Operator	Load + losses
[N]	[Label]		[MW]
1	Uzbekistan-Kabul	Uzbekistan	280
2	Turkmenistan-Kabul-Badakhsan	Turkmenistan	290
3	Kabul-Kandahar	Afghanistan	275
4	Turkmenistan-Herat	Turkmenistan	80
5	Iran-Herat	Iran	70
6	Mazar-e-Sharif TPP island	Afghanistan	25
Total			**1020**
		-Total Turkmenistan import	*370*
		-Total Uzbekistan import	*280*
		-Total Iran import	*70*
		-Total Afghanistan generation	*300*
Demand balance			
	Total demand	[MW]	1158
	Total unserved demand	[MW]	59
	Total unserved demand	[%]	5
	Simulated transmission losses	[MW]	100

Table 11.2.1-1: Stage A power generation by system segments and demand balance

Stage A of the power system expansion features all projects currently under construction. In particular the NEPS and SEPS interconnector project and the 500 kV import line from Turkmenistan to Sheberghan are in service. A 220 kV DC connection between Andkhoy and Mazar-e-Sharif is additionally established. Check Annex 11.2.1-3 for topologic allocation.

System segment 1: Uzbekistan - Kabul (UZB-Kab)

As soon as the import link from Turkmenistan is strengthened 300 MW provided by Uzbekistan may be used for feeding Kabul. The load forecast figures of the three substations of Kabul North, Kabul North West and Dehsabz South sum up to 219 MW. The remaining 81 MW from Uzbekistan feed the substations at Aybak and Pol-e-Chomri.

In order to leave the opportunity to feed from Turkmenistan via Pol-e-Chomri to Kunduz one circuit of the DC line Naibabad to Pol-e-Chomri is used for feeding Kabul from Uzbekistan. The line Pol-e-Chomri to Kabul will be operated in split circuit likewise as the Turkmen import will be used to feed the load at Chimtala.

To limit the voltage drop on the then high loaded importing lines compensation equipment will be necessary at Chimtala and Pol-e-Chomri. Following values have been determined for winter peak load:

- Naibabad: 50 $Mvar_{cap}$
- Chimtala: 70 $Mvar_{cap}$
- Pol-e-Chomri: 100 $Mvar_{cap}$

Figure 11.2.1-1gives an indication about the consequences to the bus voltage profile. All voltages are in between 0.96 p.u. and 1.05 p.u. 70 % of which in between 0.98 and 1.02 p.u.

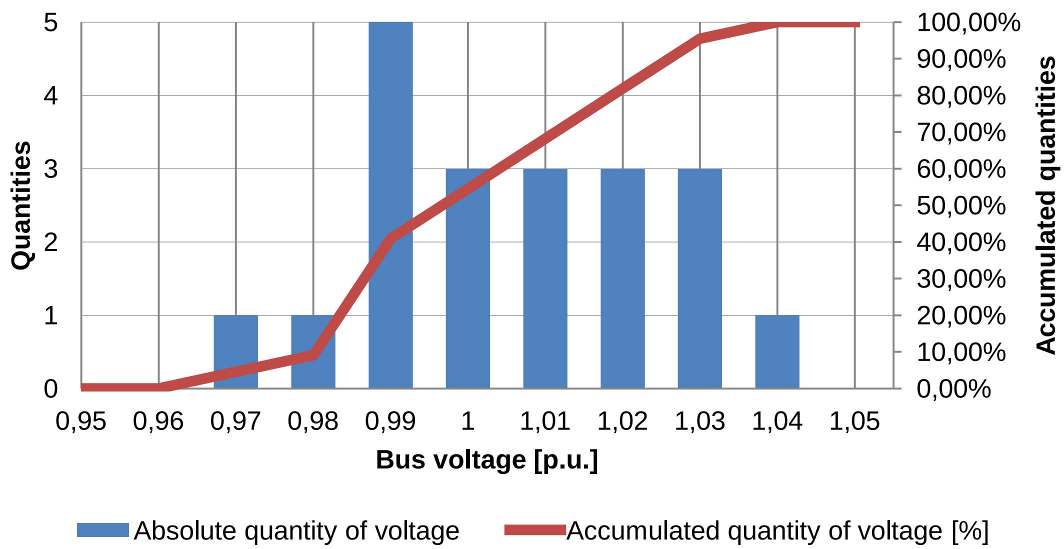


Figure 11.2.1-1: Absolute and accumulated quantities of occurance of bus voltage

This high quality voltage profile is however highly depending on load as Figure 11.2.1-2 indicates. It shows the dependence of the voltage of main buses to a load increase. The voltages of 110 kV and 20 kV buses have a slope of nearly -1.5 % / MW. That is a 10 MW incremental step of load results in a reduction of voltage of 15 %. This indicates that the system is highly volatile and weak to load changes. The system performance has to be improved by applying switchable compensation equipment. The improving effect is shown in Figure 11.2.1-3. The PV-curve slope is reduced to nearly a hundredth.

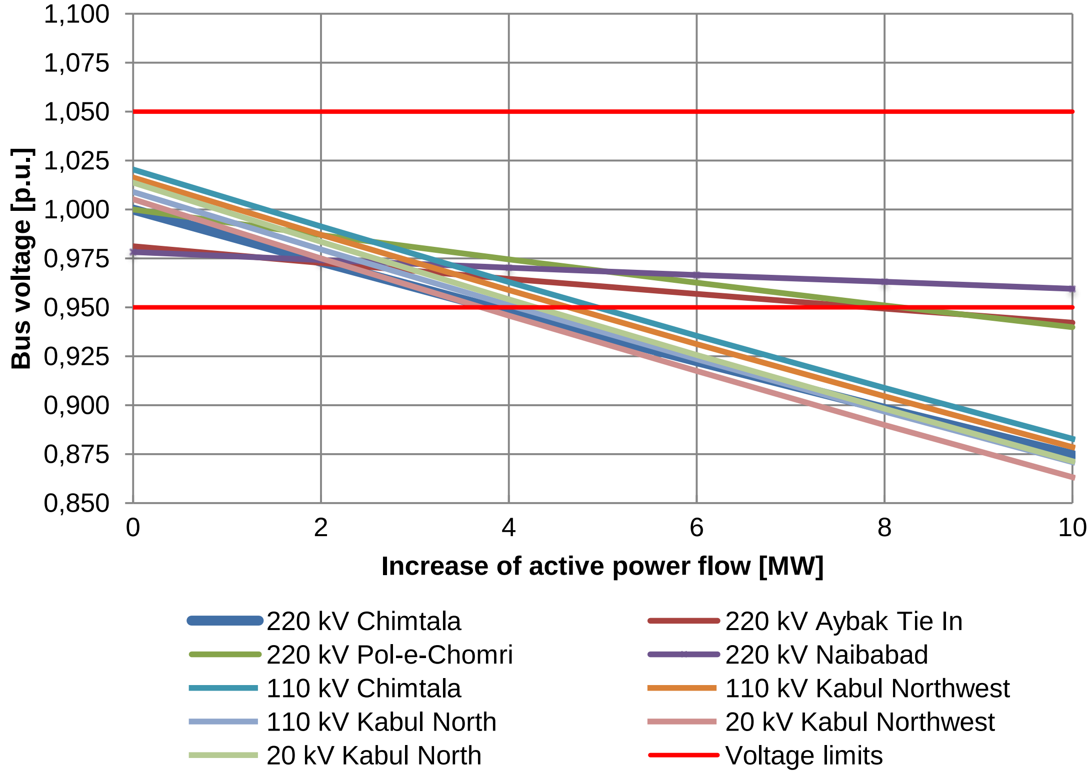


Figure 11.2.1-2: Sensitivity of bus voltage to active power, fixed shunt compensation

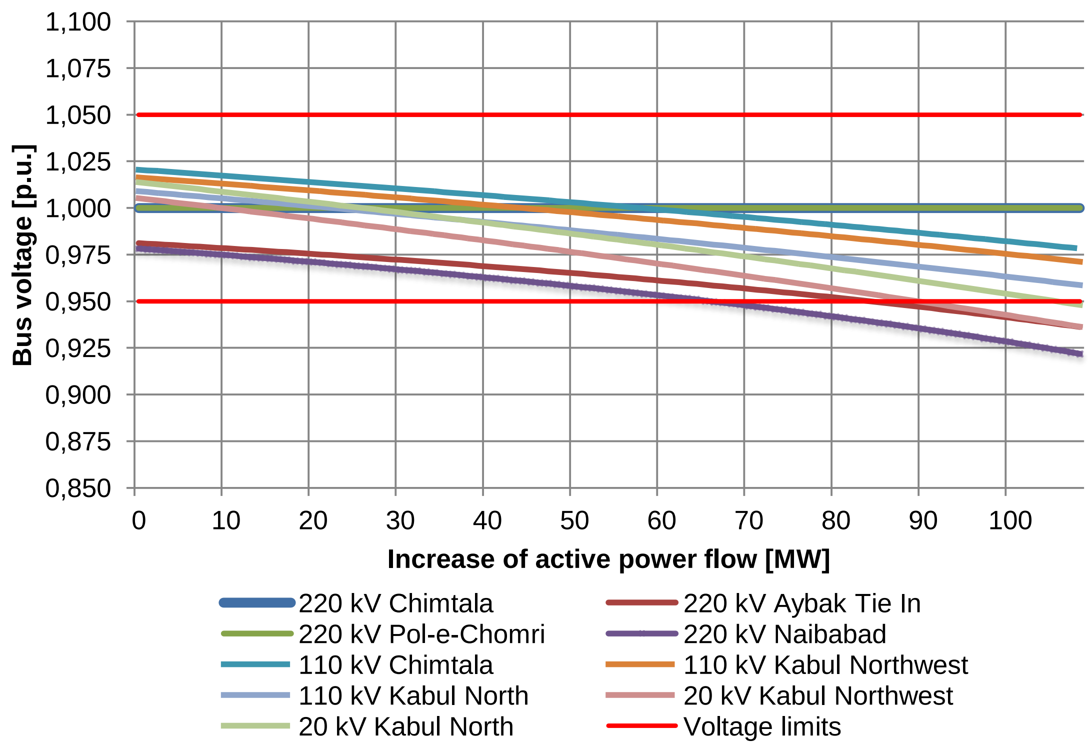


Figure 11.2.1-3: Sensitivity of bus voltage to active power, switching shunt compensation

The maximum size of the switched shunt equipment is determined by Table 11.2.1-2.

Relative load increase	[%]	0%	10%	20%
Absolute load increase	[MW]		25	50
Load	[MW]	248	272	297
Shunt compensation size				
Chimtala	[$Mvar_{cap}$]	70	95	130
Pol-e-Chomri	[$Mvar_{cap}$]	100	130	170

Table 11.2.1-2: Shunt compensation size depending on load increase

According to the consultants experience the equipment should be designed to a 10 % increase of load. The final size of the compensation devices is:

- Naibabad 50 $Mvar_{cap}$
- Chimtala 95 $Mvar_{cap}$
- Pol-e-Chomri 130 $Mvar_{cap}$

System segment 2: Turkmenistan - Maiwand - Kabul - Badakshan (TKM-Mai-Kab),

The import capacity from Turkmenistan of 300 MW exceeds by far the total load (P_{2015} = 93.6 MW) of the provinces Faryab, Jowzjan, Sar-e-Pol and Balkh. Thus the province of Kunduz, Takhar and Badakhshan as well as the load centers Chimtala and Bagram at Kabul can be served. This however requires split bus operation at Naibabad, Pol-e-Chomri and Chimtala and sufficient import line capacity to transfer 350 MVA from the Turkmen Afghan border at Aqeena. This emphasizes the importance of the 500 kV import line currently under development and an expansion of that line to Mazar-e-Sharif.

The 500 kV import line from Turkmenistan ending at Sheberghan will be operated on 220 kV firstly. This is due to:

- Begin of 500 kV operation at Turkmenistan in unknown (2020 at the latest),
- 500 kV / 220 kV transformers are costly hence should only be used when necessary,
- 500 kV input power will be necessary from Stage B 2020 on (when load has risen accordingly),
- Inter bus transformers 220 kV / 110 kV at Andkhoy, Sheberghan and Mazar-e-Sharif will be necessary in all phases and must be built immediately,
- Conductor carrying capacity necessary for import of 350 MVA is easily reached by the 500 kV conductor layout.

The results of the load flow analysis are shown in Figure 11.2.1-4. All voltages remain between 0.95 p.u. and 1.05 p.u. when compensation equipment is applied:

- Chimtala 50 $Mvar_{cap,}$
- Maimana 10 $Mvar_{cap,}$
- Faizabad 25 $Mvar_{ind.}$

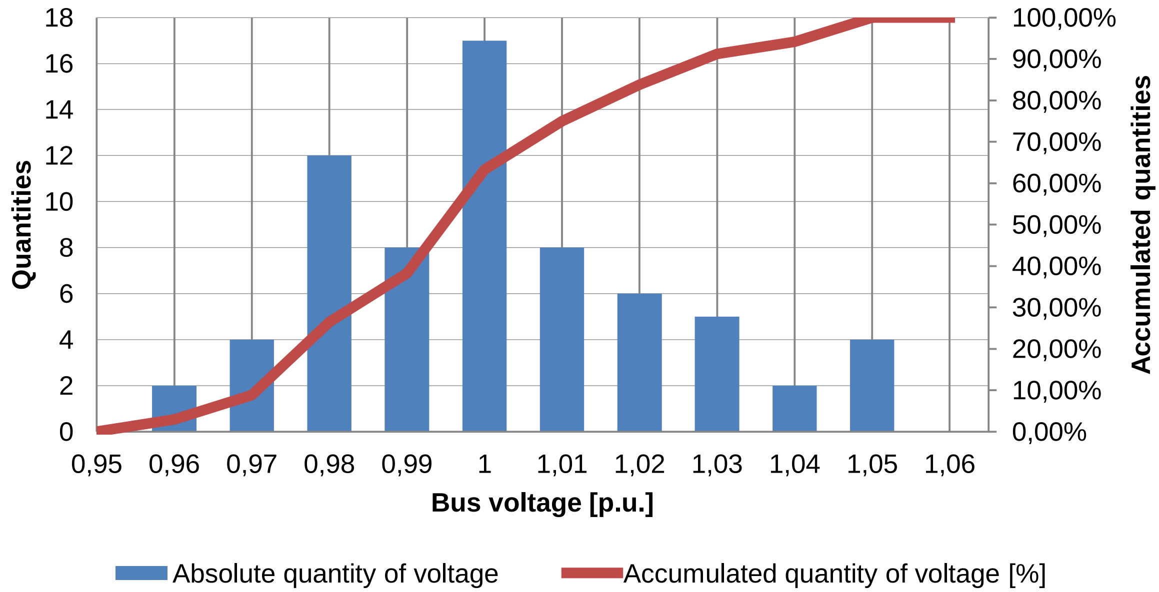


Figure 11.2.1-4: Absolute and accumulated quantities of occurance of bus voltage

Figure 11.2.1-5 shows the sensitivity of the bus voltages to a load varying from -10 MW (-3 %) to 30 MW (+10%). The bus voltages are highly stable over the load range. Low load operation may however require reduction of the VAR input from the shunt capacitors at Maimana and Chimtala. In order to balance the VARs according to load it is therefore advised to install switchable compensation equipment only.

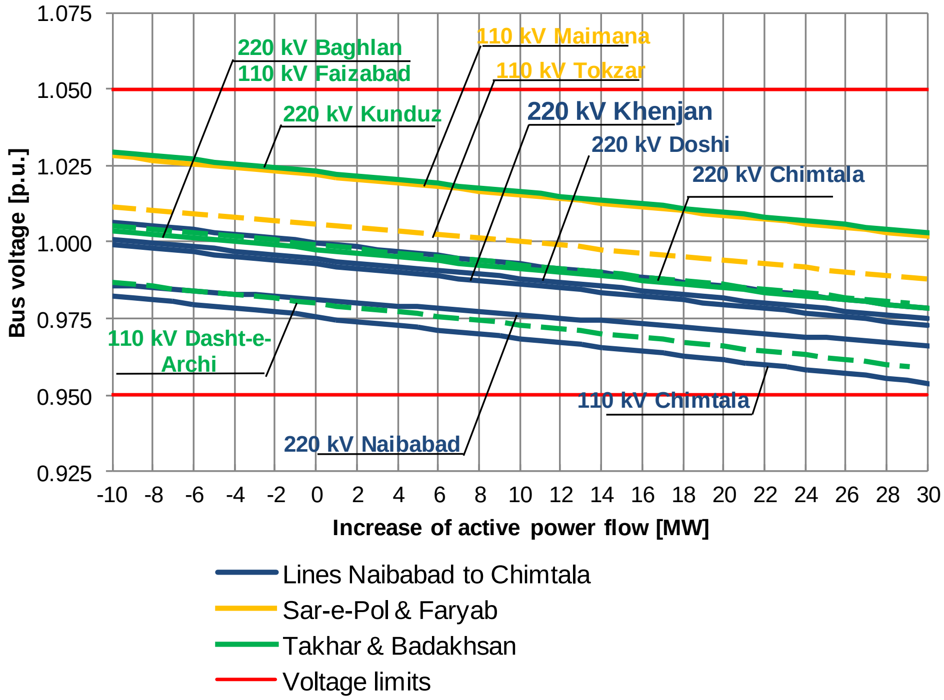


Figure 11.2.1-5: Bus voltages at different areas of the TKM-Mai-Kab network segment

System segment 3: Kabul - Kandahar (Kabul-Kandahar)

As the loads of Chimtala, Kabul North and Kabul Northwest are fed by uzbek and turkmen imports, afghan generation capacity is reserved for loads at Kabul east and load centers at Kandahar and Helmand (so called SEPS). The afghan fed Kabul network consists of the substations Kabul Town (Breshna Kot), Kabul East, Bothkak, Pol-e-Charki, Sarobi, Jalalabad and Mehtarlam with a total load of 192 MW (including transmission losses). An uplink to 220 kV level at Sarobi HPP station connects the afghan generation capacity to the 220 kV NEPS-SEPS interconnector at Arghandi. This connection link starts at Arghandi substation and passes the substations of Maydan Shar, Sayd Abad, Ghazni, Quabaragh, Gelan and Qalat-e Gilzay to Kandahar city. At Kandahar the 220 kV is transformed down to 110 kV feeding the substations Maiwand, Lashkargah, Sangin North and Musa Qala with a total load of 85 MW (including transmission losses).

Generators will be placed at both ends of the interconnector namely

- Kabul generation
  - Tarakhil TPP
  - Mahipar HPP
  - Naghlu HPP
  - Sarobi HPP
  - Darunta HPP

- SEPS generation at
  - Kandahar TPP
  - Kajaki HPP

The result of the power flow calculation is given Figure 11.2.1-6. Two operation scenarios shown are:

- Scenario I: Generation units at Kandahar are out of service,
- Scenario II: Generation units at Kandahar are in service.

The scenarios represent the best and worst case operation of the NEPS-SEPS interconnector. With generation at Kandahar in service (in total about 41 MW) a significant share of load will be served locally thereby reducing the power to transmit via the NEPS-SEPS interconnector. It also helps to maintain the voltage at the required level by providing VARs to the network. Figure 11.2.1-6 shows that bus voltages can be maintained at a acceptable level in both cases. Without generation at Kandahar however the overall bus voltages shift to an insignificant lower average value. This is a consequence of the lacking voltage support from Kandahar generation.

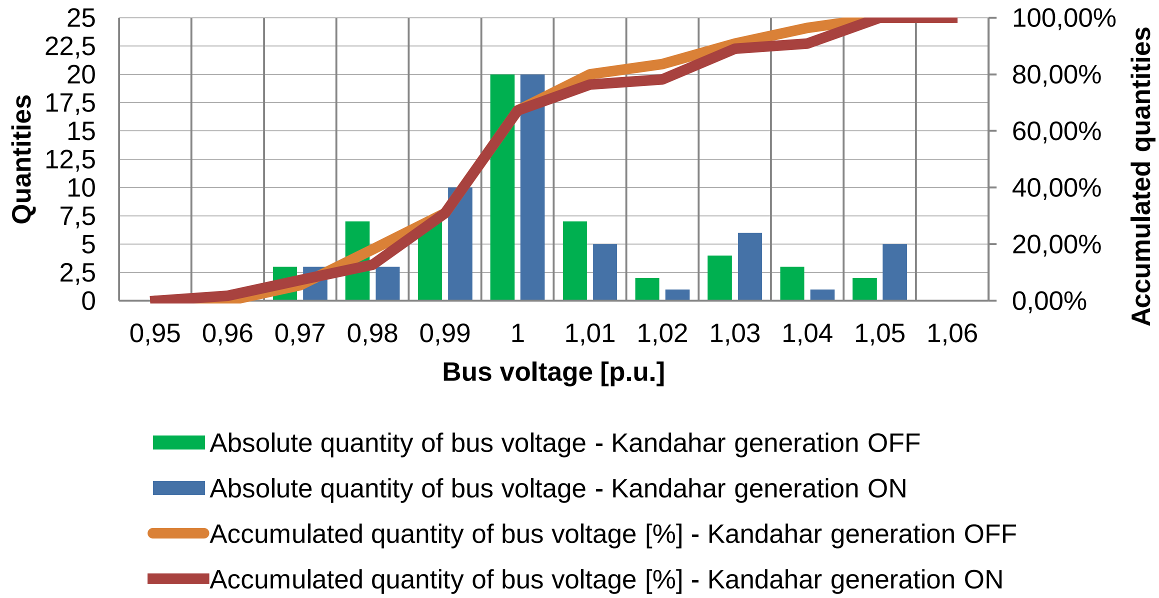


Figure 11.2.1-6: Absolute and accumulated quantities of occurance of bus voltage depending on Kandahar generation status

In general neither scenario I nor II is critical to the bus voltages. Nevertheless proper compensation equipment has to be applied in both cases at Arghandi in order to maintain the voltages at the NEPS-SEPS interconnector at an acceptable level (voltages of 1.10 and above were calculated otherwise). Figure 11.2.1-7 shows the impact of the compensation equipment placing. If a possible bandwidth of -10 MW (-20 %) to +10 MW (+20%) is applied on the summarized SEPS load nearly all voltages remain within acceptable limits. A violation of limits occurs at Quabaragh 220 kV bus where voltage rises to 1.05 p.u. under the condition of uncompensated minimum load with no generation in service at Kandahar. In order to prevent the rise of voltage in this case and due to the uncertainty of Kandahar generation the installation of fixed reactor compensation at Kandahar and Arghandi is advised.

Compensation equipment calculates to:

- Kandahar: 10 $Mvar_{ind}$
- Arghandi: 40 $Mvar_{ind}$

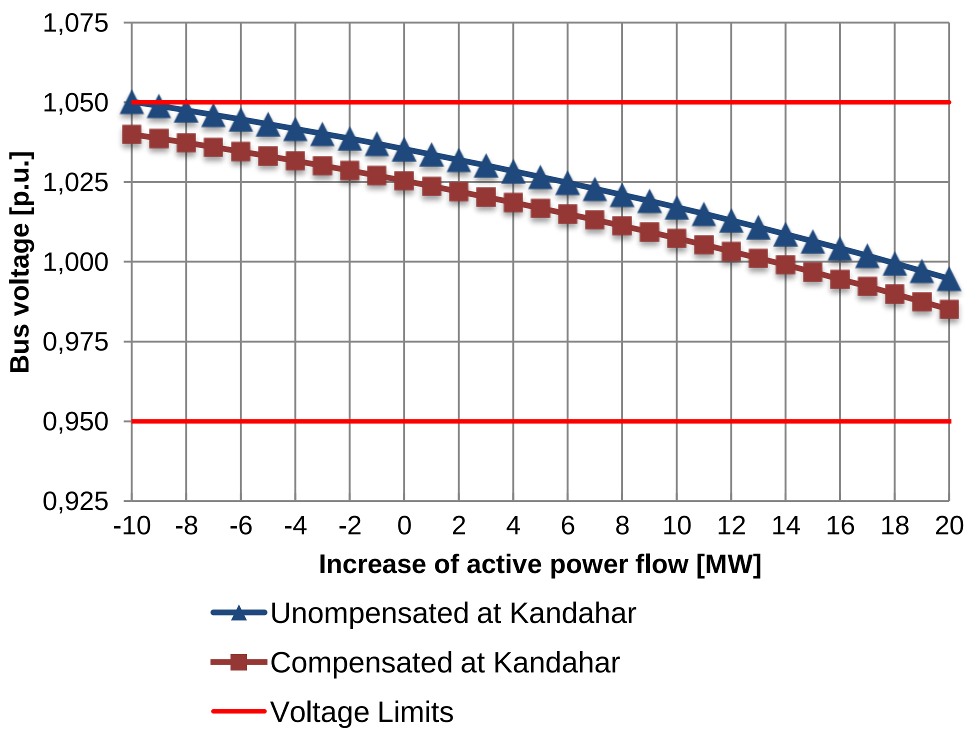


Figure 11.2.1-7: Sensitivity of bus voltage at Qalat-e Gilzay to compensation at Kandahar (10 $Mvar_{ind}$) and change of total load at SEPS, no generation at Kandahar

Segment 4: Turkmenistan - Rubat Sangi - Noor Jahad, Herat (TKM-Herat)

The import line from Turkmenistan to Noor Jahad is constructed on 220 kV but currently operated at 110 kV for unknown reasons. For the sake of a worst case analysis it is assumed that in 2015 the system segments feeding Herat will remain at the current status. No line extension is planned. In order to improve the voltage level at Noor Jahad a switched shunt of 70 $Mvar_{cap}$ must be installed at Noor Jahad. Network calculations prove the bus voltages to be kept within 0.95 p.u. and 1.05 p.u. consequently.

Compensation equipment to be installed:

- Noor Jahad: 70 $Mvar_{cap}$.

Segment 5: Iran - Ghorian - Mir Dawoud, Herat (IRA-Herat)

In order to improve the voltage level at Mir Dawoud a switched shunt of 35 $Mvar_{cap}$ should be installed at Mir Dawoud. Network calculations prove the bus voltages to be kept within 0.95 p.u. and 1.05 p.u.

Compensation equipment to be installed:

- Mir Dawoud: 35 $Mvar_{cap}$.

Segment 6: Mazar-e-Sharif TPP - Mazar-e-Sharif (Mazar-e-Sharif TPP)

The thermal power plant at Mazar-e-Sharif is connected to the local fertilizer fabric. According to data collected 48 MW are usable for serving the grid as soon as a transmission line is established between the plant and Mazar-e-Sharif substation.

It is therefore assumed that the TPP at Mazar-e-Sharif feeds 24 MW of local loads of Mazar-e-Sharif using a transmission line at 110 kV. No compensation equipment is necessary.

Note that the regulations of the Turkmen grid (which is feeding Mazar-e-Sharif mostly at this stage) do not allow any afghan generation to synchronize. This system segment therefore has to remain islanded from the Mazar' grid. The amount of load served by the local TPP is restricted by switching options in Mazar-e-Sharif.

Cost of compensation equipment

The compensation equipment cost sum to 10.4 million US$. Check Table 11.2.1-3 below.

System segment	Substation	Voltage U	Rated B	Type	Additional cost
		[kV]	[MVAR]	[CAP/IND]	[M$]
UZB-Kab	Naibabad	220	50	CAP	1
UZB-Kab	Chimtala	220	100	CAP	2
UZB-Kab	Pol-e-Chomri	220	130	CAP	2.6
TKM-Mai-Kab	Chimtala	220	50	CAP	1
TKM-Mai-Kab	Maimana	110	10	CAP	0.2
TKM-Mai-Kab	Faizabad	110	25	IND	0.5
Kab-Kand	Kandahar	220	10	IND	0.2
Kab-Kand	Arghandi	220	40	IND	0.8
TKM-Herat	Noor Jahad	110	70	CAP	1.4
IRA-Herat	Mir Dawoud	110	35	CAP	0.7
TOTAL					**10.4**

Table 11.2.1-3: Cost of compensation equipment Stage A 2015

11.2.2 Stage B: the planned power system state in 2020

As a first major step towards a unified national grid the Afghan and the Turkmen systems will be synchronized at Pol-e-Chomri with the means of a Back-2-Back station in 2020. As the first part of the envisaged Back-2-Back hub at Pol-e Chomri it allows afghan operators to synchronize domestic generation with bulk imports thereby increasing reliability of supply. However, as the hub has to be installed stepwise and despite one existing back-2-back station, islanded operation will still be in place in Stage B 2020: In total four system segments will be serving afghan load:

1. Turkmenistan - Afghanistan (TKM-AFG-Kab),
2. Uzbekistan - Kabul (UZB-Kab),
3. Turkmenistan - Noor Jahad, Herat (TKM-Herat),
4. Iran - Mir Dawoud, Herat (IRA-Herat).

The according single line diagram is given in **Annex 11.2.2-1** for summer operation and **Annex 11.2.2-2** for winter operation. **Annex 11.2.2-3** provides the topologic allocation. A list of all compensation equipment and costs is provided in Table 11.2.2-3 on page 11-20.

11.2.2.1 Network simulation conditions

Major transmission projects
In total 30 new lines are proposed in advance of 2015. Top priority projects are

- 500 kV SC line from Sheberghan to Mazar-e-Sharif,
- 500 kV SC line from Mazar-e-Sharif to Pul-e-Chomri,
- 500 kV SC line “Bamyian Route” from Pul-e- Chomri via Ishpushta, Bamyian to Arghandi at Kabul south,
- 220 kV SC line from Arghandi to Chimtala,
- 220 kV DC line from Arghandi to Kandahar via Sayd Abad, Ghazni and Gelan (NEPS-SEPS interconnector).

Load scenarios
As the import scheme does not change in 2020 it is reasonable to consider the same load scenario: as hydroelectric power from Tajikistan is available only in summer-times it will be used to feed the provinces of Kunduz, Takhar and Badakshan. Check Annex 11.2.2-1 for according grid configuration SLD.

In winter operation this part of the grid will be fed from turkmen-afghan grid synchronized at Pol-e-Chomri. Check Annex 11.2.2-2 for according grid configuration SLD.

11.2.2.2 Results of power flow calculations

Table 11.2.2-1 sums up the fundamental outcomes for generation and demand of the load flow calculations at the winter operation scenario.
The load flow calculation results for development Stage B for winter operation scenario are given within the single line diagram in **Annex 11.2.2-4**.

98 % of the afghan winter time peak load will be covered by domestic generation and imports. Load shedding is not necessary. 2% of power demand however resides in remote areas and cannot be energized by the transmission grid. The simulated transmission loss on high voltage level is 9 %.

Power generation			
Power system segment		Operator	Load + losses
[N]	[Label]		[MW]
1	Turkmenistan - Afghanistan	Afghanistan	1210
2	Uzbekistan - Kabul	Uzbekistan	260
3	Turkmenistan - Herat	Turkmenistan	120
4	Iran-Herat	Iran	80
Total			**1670**
		-Total Turkmenistan import	*370*
		-Total Uzbekistan import	*280*
		-Total Iran import	*70*
		-Total Afghanistan generation	*300*
Demand balance			
	Total demand	[MW]	1807
	Total unserved demand	[MW]	40
	Total unserved demand	[%]	2
	Simulated transmission losses	[MW]	148

Table 11.2.2-1: Stage B power generation by system segments and demand balance

Stage B 2020 features a big leap towards a unified national afghan grid. Two 500 MW Back-2-Back stations will be installed at the feeding bus in Pol-e-Chomri allowing 1000 MW to be imported via a 500 kV line from Turkmenistan into the afghan grid. The Afghan-Turkmen system segment (named after the suppliers) therefore serves for the greatest share of the Stage B 2020 load. Three more separated grid segments will be established, namely the Uzbek import to Kabul and the Turkmen and Iran in-feed to Herat.

System segment 1: Afghan power system (TKM-AFG-Kab)

The main feature of the Afghan power system are two 500 MW Back-2-Back stations at Pol-e-Chomri operated in parallel. They enable transfer capacity for import power from the turkmen to the afghan grid. 1000 MW of Turkmen imports may be injected to the afghan grid at Pol-e-Chomri making the substation the central backbone of the Afghan grid. Incoming Turkmen power must be distributed to remote areas and connect to domestic generated power. This is the purpose of two major projects:

Bamyian route

As the Salang pass currently restricts power exchange between Pol-e-Chomri and Kabul an alternative route is necessary given the load increase projected for 2020 and beyond. In order to minimize power transmission losses and with respect to the power plant projects Dara-i-Suf and Ishpushta (both projected for 2032) a 500 kV line across the Bamyian route therefore is advised.

Grid connection of coming Kunar sites

The hydro power project at Kunar province, "Kunar cascade", comprises in total 1100 MW of generation capacity portioned to two hydro power plants. These are projected to be in service in 2032, either as a major contribution to a self-sufficient afghan power system or as a source of power export to Pakistan. In both cases power to be produced in Kunar has to be connected to the afghan grid. The necessary power transmission line is projected to end at Jalalabad and to be in service in 2020. At this stage it will initially serve as power distribution line serving the loads at Kunar and Nurestan. It is a designated 500 kV line with the length of 100 km to 130 km. It will be connected (initially) to the Bamyian route via a 220 kV link between Jalalabad and Arghandi.

Both of these projects are of high influence on the network calculations and load flow results. Turkmen bulk power arriving at Pol-e-Chomri, the physical centre of the network, and the absence of distributed domestic generation raises the issue of power transmission to load centers of Kabul (718 MW), Helmand and Kandahar (both 137 MW) and remote load centers as Nurestan and Kunar (both 15 MW) and Badakshan (26 MW) and Faryab (36 MW). The principle approach of load connection is addressed in the following.

Kabul Load

Kabul load will be served by one west and one south side 220 kV line beginning at Arghandi. The southern line, already established in 2015 passes the projected area of the Aynak copper fields and ends at the Sarobi HPP. From there the power is injected to the eastern 110 kV network connecting Sarobi, Jalalabad and Metharlam and to the western 110 kV network supplying Kabul east. The second 220 kV line passes Kabul beginning at Arghandi on the west side and ends in Chimtala. There the power is transferred to the 110 kV level and distributed to Kabul Northwest, Kabul North and Kabul central stations. Both lines are to be considered as the beginning of a 220kV ring of lines surrounding Kabul in 2025 thereby improving supply reliability and reducing power transmission losses.
Additionally a third interconnection at Arghandi feeds Kabul via a 110 kV line starting at Arghandi and ending at Breshna Kot substation.

SEPS Load

Arghandi also serves as the sending end for the NEPS-SEPS interconnector. From there power will be wheeled to the substations situated in the provinces of Wardak, Logar, Paktia, Ghazni, Khost, Paktika, Zabul, Uruzgan and eventually Kandahar and Helmand. At SEPS the power plant of Kajaki will be integrated to the afghan grid.

Nurestan and Kunar

Beyond Jalalabad the loads of Nurestan and Kunar are connected via a 500 kV line. This line may be operated on 220 kV until the Kunar cascade is in service requiring a high voltage tie-in line.

Badakshan, Takhar and Kunduz

As tajik power is seasonal hydro the provinces in the north east of Pol-e-Chomri will be connected to the afghan power system. The vital part of the connection is a 220 kV line from Taluqan to Kukcha, serving as a 220 kV backbone for the north-eastern provinces. Economic optimization shows Kukcha will not be built within the projected time horizon. As, however, “soft” aspects as the political desire to scale down power imports or to increase power export are not reflected in the economic analysis, it seems reasonable to maintain the option of connecting Kukcha to the grid. It is therefore advised to use a SC line for the 220 kV transmission line. This line may be laid on DC towers, hence, not precluding future decisions in favor of Kukcha.

Inclusion of Khulm to Faryab

The gas fired power plant of Sheberghan will be feeding into the afghan power grid. This is achieved by connecting Mazar-e-Sharif, Sheberghan and Andkhoy via a 220 kV transmission line to Naibabad and Pol-e-Chomri. The province of Faryab and associated load centers are consequently connected to the afghan grid via Andkhoy.

Simulation results for the afghan power system show voltages are kept within limits. A sensitivity analyses was performed to identify significant voltage drops or raises. Depending on transformer tap adjustments all voltages could be maintained within acceptable limits. Switchable shunts have to be installed to prevent inadmissible voltage drops at 110% of nominal load.

It is advised to install switchable equipment to allow adjustments to the actual load situation:

- Chimtala: 10 $Mvar_{cap}$
- Arghandi: 140 $Mvar_{cap}$
- Kabul North: 60 $Mvar_{cap}$
- Kandahar: 50 $Mvar_{cap}$

Figure 11.2.2-1 shows the dependency of the bus voltages to load increase or decrease: If tap ratios at transformers are adjusted accordingly no violations of voltage limits are simulated with one exception: The bus voltages at Maimana in case of low load. To prevent unacceptable voltage rise a more detailed investigation in shunt reactor sizing should be performed when more accurate data to the actual loads are available. From the perspective of the power sector master plan no measures need to be advised.

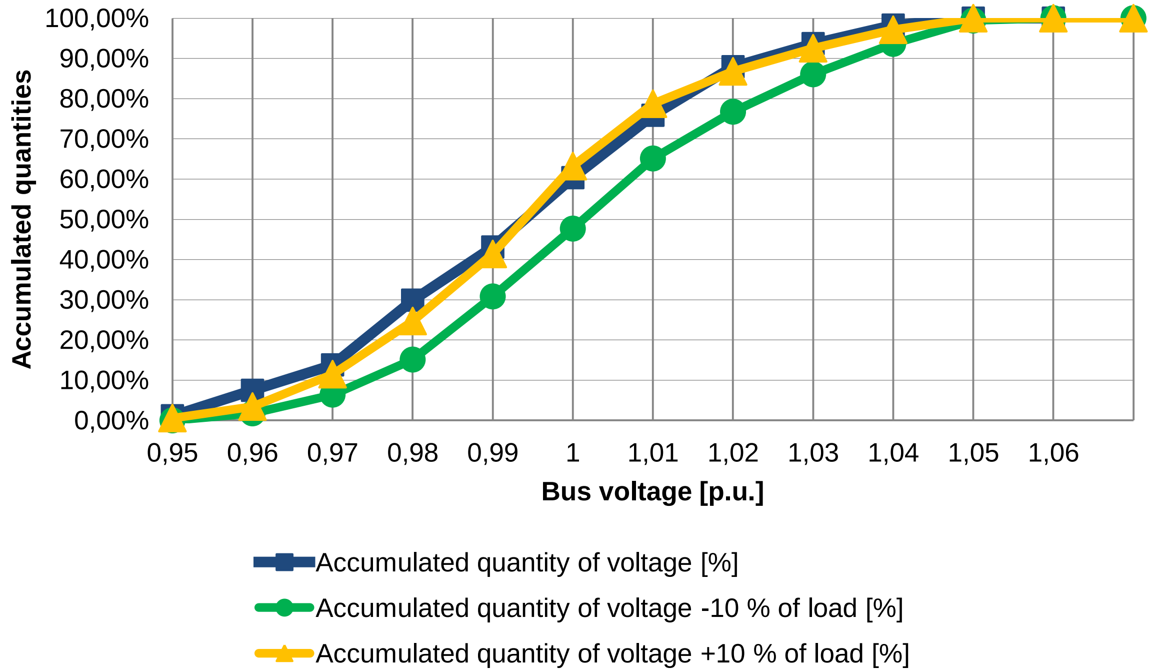


Figure 11.2.2-1: Sensitivity of accumulated bus voltage quantities to load variation

Overloading occurs at the 110 kV line between Jalalabad and Naghlu power plant and the associated 220 kV / 110 kV transformer feeding to Naghlu 110 kV. As however in Stage C 2025 loading/generation dispatch will change and the 220 kV infeed at Chimtala will increase the line loading decreases consequently. Further, as cold temperatures temporarily increase line capacity in winter no additional line from Jalalabad to Naghlu is advised. The same applies basically for the 220 kV / 110 kV transformer at Naghlu. It is nevertheless advised to add a transformer as it the feed-in reliability needs to be increased. The following transformers will feed in Kabul in Stage B 2020:

Substation	Count	Rated S	High voltage level	Low voltage level	Loading
		[MVA]	[kV]	[kV]	[%]
Chimtala	3	160	220	110	78
Arghandi	3	300	500	220	82
Arghandi	2	100	220	110	70
Sarobi HPP	2	100	220	110	55
Naghlu HPP	2	100	220	110	49

Table 11.2.2-2: Step down transformers at Kabul, Stage B 2020

System Segment 2: UZB supply to Kabul (UZB-Kab)

As the uzbek power system will not be able to synchronize in 2020 its in-feed to Afghanistan still has to be physically segmented from the then-unified turkmen afghan system. Therefore

Naibabad, Pol-e-Chomri and Chimtala will remain in split bus operation connecting loads fed from Uzbekistan at Dehsabz South, Bagram, Kapisa, Golbahar, Rukha, Ghorband, Khenjan, Pol-e-Chomri and Aybak.

Network extensions integrate the substations of Panjshir, Parvan and Kapisa. A 220 kV transmission line connects Bagram and Kapisa adding another 60 km to the (yet unfinished) 220 kV line ring around Kabul.

As the total loading to the uszbek system does not change, since it is limited by PPA to 300 MW, voltage and line loading behave as assessed in Stage A 2015. Further performance improvement measurements are not necessary.

System segment 3: Turkmenistan to Noor Jahad, Herat (TKM-Herat)

The transmission line connecting Torghondui to Noor Jahad substation in Herat is built on 220 kV configuration and currently operated on 110 kV. In order to increase the transmission capacity it is envisaged to operate the line on its rated voltage as soon as possible. Here, it is assumed that this stage is reached in 2020 at the latest. The loads of Herat, that is the substations Rubat Sangi and Noor Jahad, will be fed from Turkmenistan. In total 110 MW will be exported to the Herat province from Turkmenistan.

As it is aimed to integrate Herat to the north east power system a 220 kV connection between Faryab and Herat becomes necessary. The connection will be established in the period of 2020 to 2025. The 2020 calculations were carried out including one line from Noor Jahad to Qalat-i-Naw on 220 kV level to test the systems sensitivity to an early extension of the Herat grid. Even in this case network calculations show no limit violations in load or inadmissible voltage drop. The necessity though of the compensation equipment implemented in Stage A 2015 is underlined by the power flow results provided on page 11-13.

System segment 4: Iran to Mir Dawoud, Herat (IRA-Herat)

The Iran power system will remain physically segmented from the afghan system. In 2020 basically the same operation mode as 2015 will be implied.

Network calculations show a low sensitivity to the load rise, such that no further network expansion or extension of the 2015 implemented compensation equipment is necessary.

Cost of compensation equipment

The compensation equipment cost sum to 5.2 million US$. Check Table 11.2.2-3 below.

System segment	Substation	Voltage U	Rated B	Type	Additional cost
		[kV]	[MVAR]	[CAP/IND]	[M$]
TKM-AFG-Kab	Chimtala	220	10	CAP	0.2
TKM-AFG-Kab	Arghandi	220	140	CAP	2.8
TKM-AFG-Kab	Kabul North	110	60	CAP	1.2
TKM-AFG-Kab	Kandahar	220	50	CAP	1
TOTAL					**5.2**

Table 11.2.2-3: Cost of compensation equipment Stage B 2020

11.2.3 Stage C: the planned power system state in 2025

Stage C of the power system is already close to the final projection. The main transmission line projects needed to supply afghan load are constructed. The most important change to the Stage B 2020 is the additional Back-2-Back station at Pol-e-Chomri providing the capability to inject power from the uzbek grid into the afghan power system. In the envisaged stage at the uzbek, turkmen and afghan grid synchronize at Pol-e-Chomri.

The remaining system segments in 2025 are following:

- Afghan national grid, synchronized at Pol-e-Chomri with the Uzbek or Tajik and Turkmen net,
- Import from Iran to Mir Dawoud, Herat.

Where the Iran import grid must not necessarily be active (as Herat west is then served from Afghanistan via Noor Jahad) and may be used as back-up if the PPA allows so.

The according single line diagram is given in **Annex 11.2.3-1** for uzbek import operation and **Annex 11.2.3-2** for tajik import operation. **Annex 11.2.3-3** provides the topologic allocation. A list of all compensation equipment and costs is provided in Table 11.2.3-2. on page 11-25.

11.2.3.1 Network simulation conditions

Following transmission line projects completed in 2025 are to be seen as major steps towards a unified afghan grid:

Major grid extensions

- <u>NEPS-NWPS interconnector</u>
  This transmission line connects the power from NEPS to the NWPS via Maimana, Almar, Qaisar and Qala-i-Naw. The total line length sums up to 550 km supplying the loads of Faryab, Badghis and Herat. Network calculations show that a 2x3x2 ACSR 300/50 configuration is sufficient for the power transmission.

- Closure of 220 kV ring around Kabul
  As final part of the 220 kV line ring around Kabul a transmission line between Kapisa and Naghlu HPP is built. It is meant to provide sufficient power to connect to the Baghdara HPP. The established 220 kV ring line around Kabul will provide sufficient transport capacity to firstly fully include the projected HPPs at Kunar into the afghan grid, secondly to supply the rising loads at Kabul including the Kabul New City project. It will also increase the supply reliability.

- Connection of Salma HPP and province Ghor
  To increase the reach of the afghan grid the existing network at Herat will be extended to include the projected power plant of Salma and to connect to loads at Ghor province, with Chaghcharan as projected load centre. Due to the distance of 450 km between Herat city and the remote province of Ghor a 220 kV line will be necessary.

- Closure of 110 kV ring in province Takhar
  As final segment the tie in of Cha Ab will close the transmission line ring at the provinces of Kunduz, Takhar and Badakhshan. In its northern part the ring provides 110 kV connections between four substations: Imam Sahib, Dasht-e-Archi, Rustaq, and Cha Ab. In its southern part the ring connects Kunduz, Khanabad, Taluqan, Kishem and Kunar at 220 kV.

- Integration of Herat West
  Network calculations show that the substations of Mir Dawoud and Ghorian may be fed back from the afghan network. This however requires the Iran net to disconnect from the buses at Islam Qala.

Summer operation allows the in feed from Tajikistan. The network configuration is shown in Annex 11.2.3-2. Summer operation is not further addressed here.

Calculation assumptions

The scenario calculated is in accordance with the ones used previously. Operation at winter peak load has to be seen as most critical to the network loading. The scenario used therefore assesses line loading and voltage drop under following conditions:

- Maximum peak load (winter season peak),
- Import from Turkmenistan and Uzbekistan (Pol-e-Chomri Back-2-Back hub under full load),
- Power network extended to its maximum reach (inclusion of Kandahar and Herat west).

11.2.3.2 Results of power flow calculations

Table 11.2.3-1 sums up the fundamental outcomes for generation and demand of the load flow calculations at the winter operation scenario.
The load flow calculation results for development Stage C for Uzbek import which reflects the winter operation scenario are given within the single line diagram in **Annex 11.2.3-4**.

97 % of the afghan winter time peak load will be covered by domestic generation and imports. Load shedding is not necessary. 3 % of power demand resides in remote areas and cannot be energized by the transmission grid. The simulated transmission loss on high voltage level is 8.5 %.

Stage C 2025

Power generation			
Power system segment		Operator	Load + Losses
[N]	[Label]		[MW]
1	Turkmenistan - Uzbekistan - Afghanistan	Afghanistan	2370
2	Iran-Herat	Iran	-
Total			**2370**
		-Total Turkmenistan import	*1000*
		-Total Uzbekistan import	*300*
		-Total Iran import	*-*
		-Total Afghanistan generation	*1870*
Demand balance			
	Total demand	[MW]	2452
	Total unserved demand	[MW]	82
	Total unserved demand	[%]	3
	Simulated transmission losses	[MW]	203

Table 11.2.3-1: Stage C power generation by system segments and demand balance

For completion of the mentioned major transmission line projects the main issues of voltage maintenance and transmission equipment loading will be discussed in the following.

The Stage C 2025 system comprises 76 finished transmission line projects out of 80 for the whole Power Sector Masterplan. It is designed to serve as much loads as economical reasonable. On the other hand, as the results of chapter 10.3 show, the largest power plant projects will be in service in advance of 2025. Consequently the projected power system will be fed 50 % by imports in 2025. Line loading and voltage drop along the import and major transmission lines are therefore of highest interest.

Compensation Equipment

In general network calculations reveal a high necessity of line compensation equipment due to lacking generation capacity at the borders of the grid. As the power has to be transferred from power source centres at Pol-e-Chomri (landing point for Uzbek and Turkmen power), Sheberghan, Kunar A and Kabul to remote load sinks at Badakhshan, Herat, Kandahar and Ghor voltage drops along the interconnecting lines are significant.

In prevention the following compensation shunts have to be applied:

- Sar-e-Pol 10 $Mvar_{cap}$
- Faizabad 10 $Mvar_{cap}$
- Khost 10 $Mvar_{cap}$
- Maimana 40 $Mvar_{cap}$
- Noor Jahad 125 $Mvar_{cap}$
- Rustaq 10 $Mvar_{cap}$
- Kapisa 85 $Mvar_{cap}$
- Kandahar 30 $Mvar_{cap}$ (in addition to 50 $Mvar_{cap}$ of Stage B 2020)
- Gelan 50 $Mvar_{cap}$

Network calculations do not show any line overloading. As far as the line loading is concerned the DC line NEPS-NWPS interconnector may be operated as SC. However as line loading will increase in 2032 and voltage drop on the line is significant a DC line is advised (more compensation capacity was required otherwise which would partly compensate cost savings made by operating the line as SC).

The connection of Mir Dawoud and Ghorian is established with the means of a 220 kV line from Noor Jahad to Mir Dawoud and a 220 kV / 132 kV inter-bus transformer at Mir Dawoud. Since the power systems of Afghanistan and Iran will not be synchronized both infeeds must be separated. It is however possible to jointly supply loads at western Herat by operating the Mir Dawoud substation in split bus or by limiting the island fed from Iran to Koshan or Ghorian. Hence system back up is guaranteed by doubled in-feed capacity.

Assessment of sensitivity to load changes
The assessment to load changes will not be performed as detailed as done in Stage A and Stage B. On the one hand general load forecast figures become more and more unsure in the long term, on the other hand the actual load distribution can not be predicted. As an ongoing reviewing process that keeps the Power Sector Master Plan up to date is required anyway, a detailed study of load sensitivity is not only considered dispensable it could also indicate wrong measures and hence wrong investments.

The sensitivity study is performed as comparison between line loading and voltage drops according to a nominal load P_0 and a heightened load scenario at P_h:

Scenario 1: Total load P_0 = 2160 MW;
Scenario 2: Total load P_h = 2380 MW = 1.1 · 2160 MW = 1.1 · P_0;

Where both values reflect explicitly modeled loads only, line losses are not taken into account (they are however simulated by the network calculation and must be served by the total generation).

The comparison of the network simulation results indicates the operation limits and capacitance of the advised network:

- Generally the assessment at scenario 2 shows, an interconnected power grid including the loads at Mir Dawoud and western Herat would require all power plants (including Tarakhil) to operate at their limits.

- Keeping spare capacity as back up or machine overhaul and maintenance would require load shift to Iran.

- The consequent load reduction on the NEPS-NWPS interconnector would lead to a lower line loading at the interconnecting line. Subsequently the compensation equipment at Maiwand 220 kV and partly Noor Jahad may be spared. This is however compensated by the raised compensation requirements at Mir Dawoud. Note Figure 11.2.3-1.

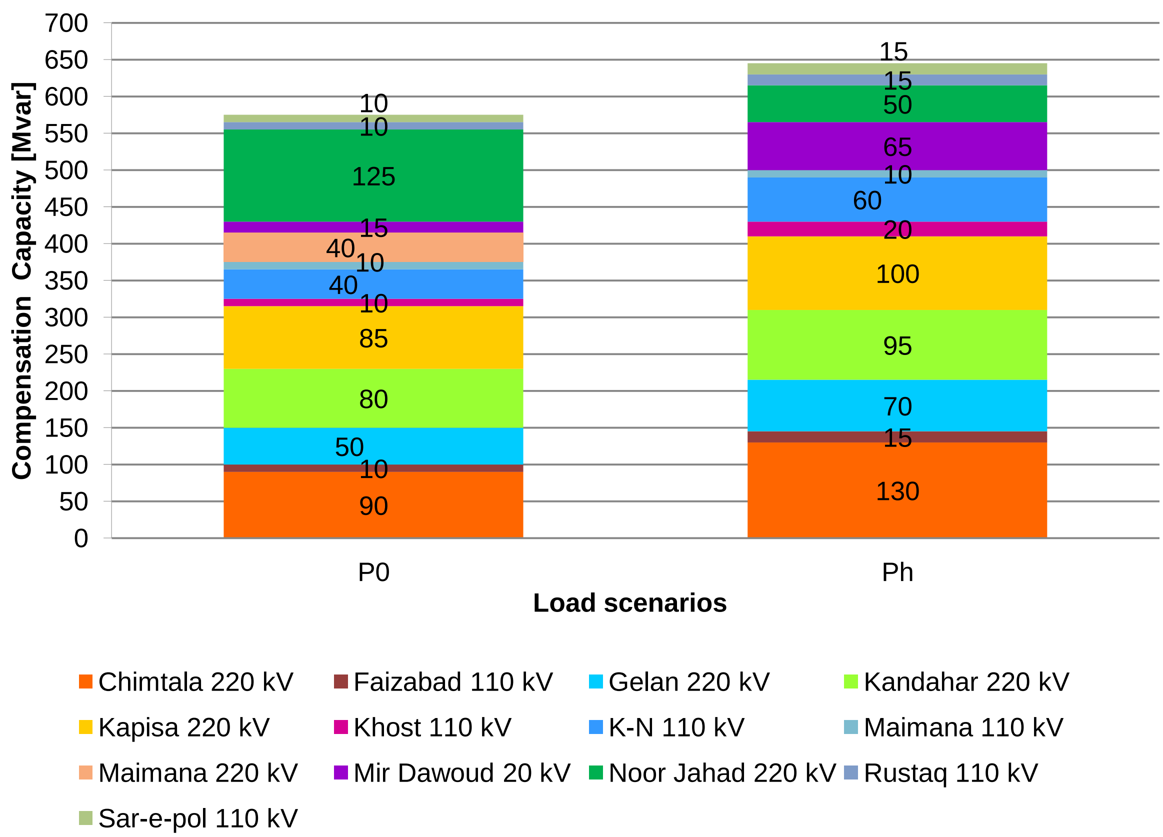


Figure 11.2.3-1: Sensitivity of compensation capacity to load

- In total the requirement for line compensation rises with increasing load (check Figure 11.2.3-1). Voltages can be maintained however within acceptable limits.

- Only four lines are loaded above 60 % in Scenario 2. Note Figure 11.2.3-2. The overall rise of line loading is uncritical.

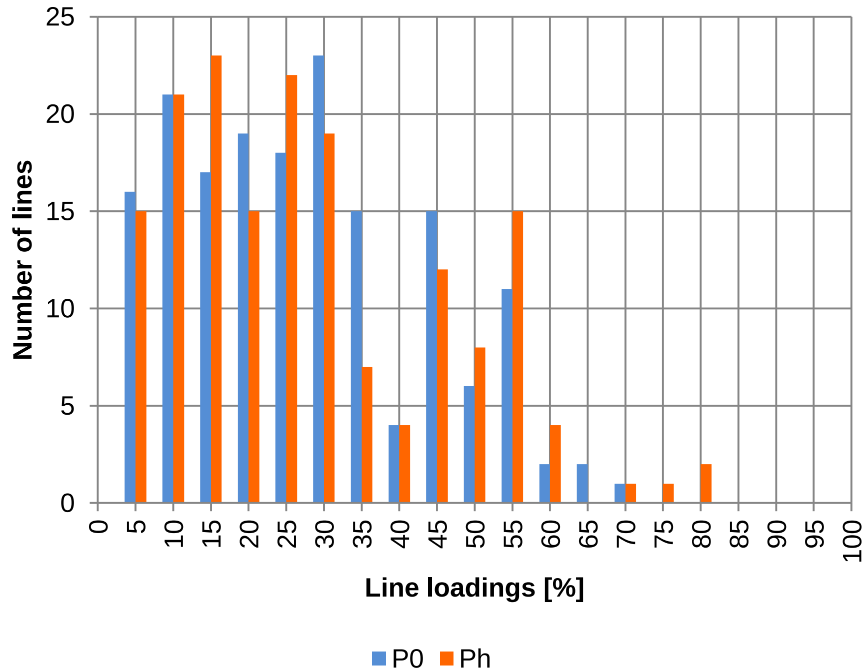


Figure 11.2.3-2: Sensitivity of line loading to load

Cost of compensation equipment

The compensation equipment cost sum to 6 million US$. Check Table 11.2.3-2 below.

System segment	Substation	Voltage U	Rated B	Type	Additional cost
		[kV]	[MVAR]	[CAP/IND]	[M$]
TKM-AFG-UZB	Faizabad	110	10	CAP	0.2
TKM-AFG-UZB	Gelan	220	50	CAP	1
TKM-AFG-UZB	Kandahar[1)]	220	80	CAP	0.6
TKM-AFG-UZB	Kapisa	220	85	CAP	1.7
TKM-AFG-UZB	Khost	110	10	CAP	0.2
TKM-AFG-UZB	Maimana	220	40	CAP	0.8
TKM-AFG-UZB	Noor Jahad[2)]	220	125	CAP	1.1
TKM-AFG-UZB	Rustaq	110	10	CAP	0.2
TKM-AFG-UZB	Sar-e-pol	110	10	CAP	0.2
TOTAL					**6**

[1)] 50 Mvar implemented in 2020;[2)] 70 Mvar implemented in 2015

Table 11.2.3-2: Cost of compensation equipment Stage C 2025, scenario P0

11.2.4 Stage D: the planned power system state in 2032

The major steps towards a national afghan grid have been undertaken in Stage C 2025. Stage D 2032 however connects all power plants and load projects into the grid.

The according single line diagram is given in **Annex 11.2.4-1** for uzbek import operation and **Annex 11.2.4-2** for tajik import operation. **Annex 11.2.4-3** provides the topologic allocation. A list of all compensation equipment and costs is provided in Table 11.2.4-2 on page 11-29.

11.2.4.1 Network simulation conditions

Major grid connections

- Full integration of Kunar A and B
  The Kunar cascade will be included to the power grid via a 500 kV transmission line beginning at Kunar and ending at Jalalabad.

- Integration of the coal fired power plants at Dara-i-Suf and Ishpushta
  The coal fired power plants will be integrated into the afghan network along the Bamyian route. From there power is wheeled to Hajigak, likewise located at the Bamyian route, and Aynak copper fields at the southern part of the 220 kV ring around Kabul.

- Integration of Baghdara HPP
  Baghdara located along the 220 kV ring will be connected to the Kabul network at the South and to Charikar at the North West.

- Integration of Kajaki HPP addition

- Integration of load centres at Aynak (copper mine) and Hajigak (iron mine).

The connecting conditions of the power system in Stage D are basically the same. Therefore the same system segmentation as Stage C applies here. The feed back to the currently iran fed substations Mir Dawoud and Ghorian (and later Koshan) allows to integrate major loads into the net being backed up by iranian imports. Again in summer operation the in feed from Tajikistan up to Pol-e-Chomri is possible. Annex 11.2.4-2 shows the according single line diagram. Summer operation is but not addressed here further.

Operation scenario

500 kV Transmission line from Arghandi to Jalalabad
In place of a network configuration that includes all major transmission line projects that were described in chapter 7.3 network calculations have been performed without the inclusion of the 500 kV transmission line from Arghandi to Jalalabad. This is due to the following considerations:

1. The line is considered rather an export than an afghan-load serving project. It is highly influenced by external conditions such as demand situation in Pakistan / India and the (yet not proven) technical feasibility of electrical connection at the afghan / pakistani - border. It will therefore not necessarily be built.
2. The line route proposed runs in parallel to the southern segment of the 220 kV ring surrounding Kabul. Specific resistance and inductance of high voltage lines are generally equal or lower than corresponding 220 kV transmission line values. As parallel lines of nearly equal characteristics cause lower loading for both lines an additional line will have a relieving effect to the network loading and voltage drop.
3. A major impact to the line loading comes from the Kunar cascade. Given that peak load occurs at Kabul the in-feed from Kunar to the 110 kV system in Kabul is highly critical. In order to determine the maximum stress at the interconnection point a worse case scenario, assuming extra line capacity is not available, has to be simulated.

Simulation of hydro generation
The simulation is performed at peak load occurring at winter times. Hydro power plants known to be of run-of-river type therefore must be simulated reduced operation capacity of 75 %. These are:

- Salma HPP,
- Olambagh HPP.

All thermal fired power plants with the exception of Tarakhil are set to maximum output. The remaining difference to the total peak load is covered with imports and hydro power plants known to be of daily-storage type. These are:

- Bagdhara HPP,
- HPPs of Kunar A and B,
- Sarobi HPP,
- Naghlu HPP,
- Kajaki HPP,
- Mahipar HPP,
- Darunta HPP.

Conclusion on calculation assumptions

As the basic connection scheme does not change the calculation scenario remains likewise mostly unchanged. As for the Stage C 2025 simulations the following assumptions apply for Stage D 2032:

- Maximum peak load (winter season peak),
- Import from Turkmenistan and Uzbekistan (Pol-e-Chomri Back-2-Back hub under full load),
- Power network extended to its maximum reach (inclusion of Kandahar and Herat west).

Following additional conditions apply for the Stage D 2032 simulation:

- Additional loads of Aynac copper mine and Hajigak iron mine considered,
- 500 kV line from Arghandi to Jalalabad not in service,
- Reduction of hydro power capacity at known run-of-river sites to 25 %,
- Thermal power plants fully loaded.

11.2.4.2 Results of power flow calculations

Table 11.2.4-1 sums up the fundamental outcomes for generation and demand of the load flow calculations at the winter operation scenario.
The load flow calculation results for development Stage D for Uzbek import which reflects the winter operation scenario are given within the single line diagram in **Annex 11.2.4-4**.

98 % of the afghan winter time peak load will be covered by domestic generation and imports. Load shedding is not necessary. 2 % of power demand resides in remote areas and cannot be energized by the transmission grid. The simulated transmission loss on high voltage level is 12 %.

Stage D 2032

Power generation			
Power system segment		Operator	Load + Losses
[N]	[Label]		[MW]
1	Turkmenistan - Uzbekistan - Afghanistan	Afghanistan	4070
4	Iran-Herat	Iran	-
Total			**4070**
		-Total Turkmenistan import	*1000*
		-Total Uzbekistan import	*300*
		-Total Iran import	*-*
		-Total Afghanistan generation	*3570*
Demand balance			
	Total demand	[MW]	3502
	Total unserved demand	[MW]	84
	Total unserved demand	*[%]*	*2*
	Simulated transmission losses	[MW]	480

Table 11.2.4-1: Stage D power generation by system segments and demand balance

For completion of the mentioned major transmission line projects the main issues of voltage maintenance and transmission equipment loading will be discussed in the following.

The Stage D 2032 system serves as much loads as economical reasonable. In the simulated winter scenario the projected power system will generate 70 % domestically. Line loading and voltage drop along the import and major transmission lines are therefore of highest interest.

Again network calculations reveal a high necessity of line compensation equipment due to high loaded lines transmitting power to remote distances. High loaded transmission lines lead to high voltage drops that can be observed in the simulations.

In prevention the following compensation equipment has to be applied:

Bus Name	**TYPE**	**B**
	[CAP/IND]	**[Mvar]**
Arghandi	CAP	140
Botkhak	CAP	75
Chaghcharan	CAP	25
Chimtala	CAP	295
Faizabad	CAP	10
Gelan	CAP	100
Ishpushta	CAP	80
Kabul North	CAP	120
Kandahar	CAP	100
Kapisa	CAP	40
Karuh	CAP	30
Khost	CAP	20
Khulm	CAP	200
Kishem	CAP	80
Kunduz	CAP	40
Maimanam	CAP	175
Mir Dawoud	CAP	60
Naibabad	CAP	100
Naibad	IND	-10
Noor Jahad	CAP	250
Pol-e-Alam	CAP	80
Pol-e-Comri	CAP	75
Rustaq	CAP	10
Sar-e-Pol	CAP	25
Total B2B compensation	CAP	1900
TOTAL IND		**-10**
TOTAL CAP		**4030**

Table 11.2.4-2: Compensation equipment at Stage D 2032

The extraordinary high value at Khulm of 200 $MVar_{cap}$ is subject to the high loaded transmission line between Pol-e-Chomri feeding the afghan west. The high value at Chimtala reflects the fact that Chimtala serves as major in-feed point to Kabul. The high value of 175 $Mvar_{cap}$ at Maimana is due to the high loading of the NESP NWPS interconnector which in turn is a result of lacking generation capacity at Herat. The same applies for the necessary compensation equipment at Noor Jahad.

Generally the line loading calculated is acceptable but significant. Figure 11.2.4-1 provides an indication to the portioning of line loads to the transmission lines. The majority of lines are loaded below 75 %, a overweighting share of lines is loaded between 50 % and 35 %.

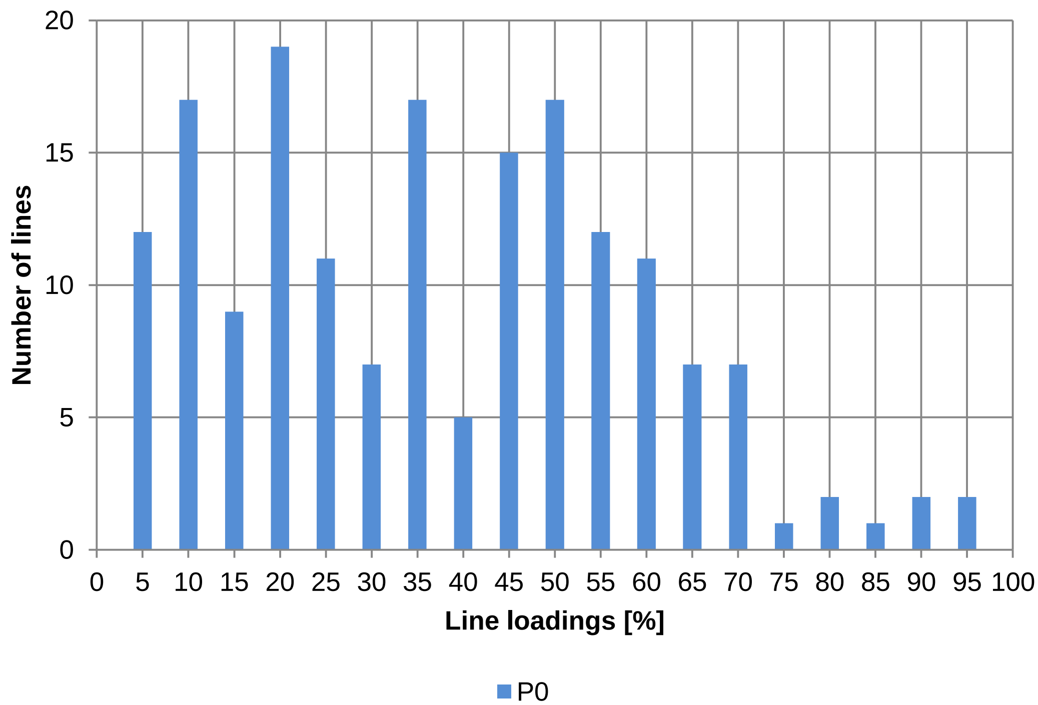


Figure 11.2.4-1: Calculated line loadings at nominal load

The highest loading occurs at following four lines:

1. 110 kV line connecting Kunduz substations (90 %)
2. 110 kV line Jalalabad to Naghlu HPP (over 100 %)
3. 220 kV line from Pol-e-Chomri to Khulm (90 %)
4. 220 kV line from Jalalabad to Sarobi HPP (85 %)

The high load of lines 1 and 3 may be reduced by applying more suitable conductor configurations. This is however subject to the carrying capacity the tower used and must be studied in detail. The overloading of line 3 is a consequence of bundling the synchronization stations at Pol-e-Chomri: It is envisaged to transfer uzbek power via Naibabad to Pol-e-Chomri. As network calculations prove one circuit of the DC constructed line is sufficient. The remaining circuit will be used to feed- back to Naibabad and further to Mazar-e-Sharif. In principle the connection between Pol-e-Chomri, North West Afghanistan and Herat is established via this circuit. Network calculations show the line operates within acceptable limits given proper compensation measures are applied. Nevertheless the issue of reliability rises urgently. This is however applies to a number of lines and must on the whole be subject to more detailed investigation.

The overloading of line 2 and 4 must be reduced by increasing the transmission capacity between Jalalabad, Sarobi and eventually Arghandi. The source of overloading is the power flow from the generation sites at Kunar to the load centers at Kabul. A relieving measure was the installation of the planned 500 kV transmission line between Arghandi and Jalalabad which would generally lead to a more uncritical current circulation. If this project was not pursued an alternative measure is increasing the line capacity by applying a more appropriate conductor configuration. This is however subject to the carrying capacity of the towers used and must also be studied further. If no alternative measures are applicable the implementation of a new 220 kV connecting line between Jalalabad and Naghlu is advised. This would however supersede the 110 kV line being built by now.

As all these results apply only for the space in time from 2032 on new investigations may then indicate more economic measures.

Cost of compensation equipment

The compensation equipment cost sum to 25 million US$. Check Table Table 11.2.4-3 below.

System segment	Substation	Voltage U	Rated B	Type	Additional cost
		[kV]	[MVAR]	[CAP/IND]	[M$]
TKM-AFG-UZB	Botkhak	110	75	CAP	1.5
TKM-AFG-UZB	Chaghcharan	220	25	CAP	0.5
TKM-AFG-UZB	Chimtala	220	295	CAP	2.7
TKM-AFG-UZB	Gelan[1)]	220	100	CAP	1
TKM-AFG-UZB	Ishpushta	500	80	CAP	1.6
TKM-AFG-UZB	Kabul North[2)]	110	120	CAP	1.2
TKM-AFG-UZB	Kandahar	220	100	CAP	0.4
TKM-AFG-UZB	Karuh	110	30	CAP	0.6
TKM-AFG-UZB	Khost[3)]	110	20	CAP	0.2
TKM-AFG-UZB	Khulm	220	200	CAP	4
TKM-AFG-UZB	Kishem	220	80	CAP	1.6
TKM-AFG-UZB	Kunduz	220	40	CAP	0.8
TKM-AFG-UZB	Maimana[4)]	220	175	CAP	2.7
TKM-AFG-UZB	Mir Dawoud[5)]	20	60	CAP	0.5
TKM-AFG-UZB	Naibabad[6)]	220	100	CAP	1
TKM-AFG-UZB	Naibabad	220	-10	IND	0.2
TKM-AFG-UZB	Noor Jahad[7)]	220	250	CAP	2.5
TKM-AFG-UZB	Pol-e-Alam	220	80	CAP	1.6
TKM-AFG-UZB	Sar-e-Pol[8)]	110	25	CAP	0.3
TOTAL					**24.9**

[1)] 50 Mvar implemented in 2025;[2)] 60 Mvar implemented in 2020
[3)] 20 Mvar implemented in 2025;[4)] 40 Mvar implemented in 2025
[5)] 35 Mvar implemented in 2015;[6)] 50 Mvar implemented in 2015

[7] 195 Mvar implemented in 2015 amd 2025;[8] 10 Mvar implemented in 2025

Table 11.2.4-3: Cost of compensation equipment Stage D 2032

11.3 Dynamic Studies

11.3.1 Introduction and objectives of the Transient Stability studies

The strength of the transmission network shall be to maintain stability following a critical fault such a zero impedance three phase fault at a 500kV, 220 and 110kV S/S, followed by fault clearing by opening and reclosing, where applicable, of protection systems. The dynamic studies are conducted using the PSS/E software package v 32 to identify any stability related constraints that will affect the ability of each part of the network to remain in synchronism following a disturbance or contingency event.

The results of the dynamic studies determines the transient stability, or first swing stability, of the system, the voltage and frequency fluctuation range in the network and the critical clearing time in different parts of the network, when subject to a severe disturbance. The system is considered stable if, under a specified set of conditions, all of its synchronous machines remain in step with one another, or having pulled out of step, regain synchronism soon afterwards.

Typical transient stability study period is in the range from 5 to 15 sec max.

The responses of the Generators in the Afghan system, following the application of 3ph faults at various critical parts of the system were monitored and the oscillations of the electrical power and rotor angles were plotted. Their excursions depend on:

- the initial operating conditions, generation and load.
- the type, duration and proximity of the fault.
- the effective impedance of the post-fault system compared to that of the pre-fault system.
- the generator inertia and sub-transient or transient reactance

11.3.2 Fault Clearing Times

The tripping time for all 500kV faults is taken as 100ms, (including relay response and CB tripping time). The tripping time for all 220 kV and 110kV faults is taken as 150ms

11.3.3 Study assumptions

In this dynamic study the following assumptions were made:

- The base case of the dynamic study is in 2032 when Afghanistan imports 1000MW from Turkmenistan and 300MW from Uzbekistan.
- Dynamic data for future generators, governors and exciters were based on typical models, as detailed on the following sections.

11.3.4 Stability criteria

The results of the simulation cases studied were evaluated based on the threshold criteria for stability applied for Afghan power system as described in Table 11.3.4-1.

Stability Type	Threshold criteria for stability
Angle (transient)	All generators in the combined system remain in synchronism for any single credible contingency.
Angle (oscillatory)	Relative rotor angle of generators within Afghnistan are sufficiently damped.
Voltage	
Steady-state	No voltage collapse
Transient recovery	Power system able to survive a 3-ph fault under N-1 contingencies.
Load Frequency	Frequency recovered to stable state without load curtailment for loss of the largest online generating unit.
HVDC	No steady-state power/voltage instability. Recovers normally from transient 3 phase faults.

Table 11.3.4-1 Stability criteria for the Afghanistan system

11.3.5 Generator, Exciter and Governor Models

Table 11.3.5-1 lists the generator, exciter and governor models used for the all Generators.

Bus Number	Bus Name	Id	Mbase (MVA)	Generator	Exciter	Governor
107	DARUNTA_20 20.000	1	4	GENROU	SEXS	HYGOV
107	DARUNTA_20 20.000	2	4	GENROU	SEXS	HYGOV
107	DARUNTA_20 20.000	3	4	GENROU	SEXS	HYGOV
117	K-NW_20 20.000	1	23.5	GENROU	SEXS	GGOV1
117	K-NW_20 20.000	2	23.5	GENROU	SEXS	GGOV1
124	MAHIPAR_20 20.000	1	23.1	GENROU	SEXS	HYGOV
124	MAHIPAR_20 20.000	2	23.1	GENROU	SEXS	HYGOV
124	MAHIPAR_20 20.000	3	23.1	GENROU	SEXS	HYGOV
128	NAGHLU_20 20.000	1	26.3	GENROU	SEXS	HYGOV
128	NAGHLU_20 20.000	2	26.3	GENROU	SEXS	HYGOV
128	NAGHLU_20 20.000	3	26.3	GENROU	SEXS	HYGOV
128	NAGHLU_20 20.000	4	26.3	GENROU	SEXS	HYGOV
138	SAROBI_20 20.000	1	11.6	GENROU	SEXS	HYGOV
138	SAROBI_20 20.000	2	11.6	GENROU	SEXS	HYGOV
139	TARAKHIL_20 20.000	1	36.8	GENROU	SEXS	GGOV1
139	TARAKHIL_20 20.000	2	36.8	GENROU	SEXS	GGOV1
139	TARAKHIL_20 20.000	3	36.8	GENROU	SEXS	GGOV1
400	KAJAKAI_11_1110.00	1	27	GENROU	SEXS	HYGOV
400	KAJAKAI_11_1110.00	2	27	GENROU	SEXS	HYGOV
401	KAJAKAI_20 20.000	1	105	GENROU	SEXS	HYGOV

Bus Number	Bus Name	Id	Mbase (MVA)	Generator	Exciter	Governor
408	KANDAHAR_1_1110.00	1	42.7	GENROU	SEXS	GGOV1
552	TAIBAT_132_1132.00	1	105	GENROU	SEXS	GGOV1
601	TAL_G1 24.000 (import from UZB)	1	1050	GENCLS	None	None
602	TAL_G2 20.000 (import from UZB)	1	525	GENROU	SEXS	GGOV1
603	TAL_G3 20.000 (import from UZB)	1	525	GENROU	SEXS	GGOV1
608	GUZAR_500 500.00 (import from UZB)	1	1050	GENCLS	None	None
700	TAJIKISTAN G500.00 (import from Tajikistan)	1	262.5	GENCLS	None	None
710	GERAN_20 20.000 (import from Tajikistan)	1	1	GENROU	SEXS	GGOV1
800	ZERNOW_20 20.000 (import from Tajikistan)	1	1	GENROU	SEXS	GGOV1
1007	AQEENA 500.00 (Import from Turkmenistan))	1	1100	GENCLS	None	None
1012	BAGHDARA HPP220.00	1	220.5	GENROU	SEXS	HYGOV
1020	DARA-I-SUF T220.00	1	1000	GENROU	SEXS	GGOV1
1034	GOLBAHAR HPP220.00	1	1	GENROU	SEXS	HYGOV
1034	GOLBAHAR HPP220.00	2	1	GENROU	SEXS	HYGOV
1034	GOLBAHAR HPP220.00	3	1	GENROU	SEXS	HYGOV
1034	GOLBAHAR HPP220.00	4	1	GENROU	SEXS	HYGOV
1035	ISHPUSHTA 220.00	1	420	GENROU	SEXS	GGOV1
1039	KAMA HPP 220.00	1	1	GENROU	SEXS	HYGOV
1039	KAMA HPP 220.00	2	1	GENROU	SEXS	HYGOV
1039	KAMA HPP 220.00	3	1	GENROU	SEXS	HYGOV
1043	KUKCHA HPP 220.00	1	1	GENROU	SEXS	HYGOV
1045	KUNAR A (SHA500.00	1	828.5	GENROU	SEXS	HYGOV
1046	KUNAR B (SAG500.00	1	315	GENROU	SEXS	HYGOV
1058	OLAMBAGH HPP110.00	1	23.6	GENROU	SEXS	HYGOV
1069	SALMA HPP 220.00	1	10.5	GENROU	SEXS	HYGOV
1075	SHEBERGHAN T220.00	1	84	GENROU	SEXS	GGOV1
1075	SHEBERGHAN T220.00	2	84	GENROU	SEXS	GGOV1
1075	SHEBERGHAN T220.00	3	84	GENROU	SEXS	GGOV1
1075	SHEBERGHAN T220.00	4	84	GENROU	SEXS	GGOV1
1075	SHEBERGHAN T220.00	5	84	GENROU	SEXS	GGOV1
1078	SURUBI/SAKUN220.00	1	1	GENROU	SEXS	GGOV1
1159	MAZ-TPP_110 110.00	1	50.4	GENROU	SEXS	GGOV1

Table 11.3.5-1 PSS/E dynamic models of Afghanistan System

The dynamic model validation in the following Section was carried out for the generating units shown, which is deemed to be representative of the behavior of all the different types of controller.

The following Table 11.3.5-2 shows representative values used for the exciter and governor models:

SEXS exciters

Model Name	Model Identifier	TA/TB	TB (> 0)	K	TE	EMIN	EMAX
SEXS		0.1	10	100	0.1	0	6

HYGOV governors

R, Permanent Droop	r, Temporary Droop	Tr (> 0) Governor Time Constant	Tf (> 0) Filter Time Constant	Tg (> 0) Servo Time Constant	VELM, Gate Velocity Limit	GMAX, Max Gate Limit	GMIN, Min Gate Limit	TW (> 0) Water Time Constant	At, Turbine Gain	Dturb, Turbine Damping	qNL, No Load Flow
0.05	0.5	4.0	0.05	0.5	0.167	1.0	0.0	2.0	1.2	0.5	0.08

GGOV1 Governors

R, Permanent droop (pu)	Tpelec, Electrical power transducer time constant(sec)	Maxerr, Maximum value for speed error signal	Minerr, Minimum value for speed error signal	Kpgov, Gov. proportional gain	Kigov, Gov. integral gain	Kdgov, Gov. derivative gain	Tdgov, Gov. derivative controller time constant(sec)	Vmax, Maximum valve position limit
0.04	1	0.05	-0.05	10	2	0	1	1

Vmin, Minimum valve position limit	Tact, Actuator time constant (sec)	Kturb, Turbine gain	Wfnl, No load fuel flow (pu)	Tb, Turbine lag time constant (sec)	Tc, Turbine lead time constant (sec)	Teng, Transport lag time constant for diesel engine (sec)	Tfload, Load Limiter time constant(sec)
0.15	0.5	1.5	0.2	0.1	0	0	3

Kpload, Load limiter proportional gain for PI controller	Kiload, Load limiter integral gain for PI controller	Ldref, Load limiter reference value(pu)	Dm, Mechanical damping coefficient(pu)	Ropen, Maximum valve opening rate(pu/sec)	Rclose, Maximum valve closing rate(pu/sec)	Kimw, Power controller (reset) gain	Aset, Acceleration limiter setpoint(pu/sec
2	0.67	1	0	0.1	-0.1	0.002	0.01

Ka, Acceleration limiter gain	Ta, Acceleration limiter time constant(sec)	Trate, Turbine rating(MW)	db, Deadband	Temperature detection lead time constant, sec.	Temperature detection lag time constant, sec.	Maximum rate of load limit increase	Maximum rate of load limit decrease
10	0.1	0	0	4	5	99	-99

Table 11.3.5-2 Representative exciter and governor parameters

11.3.6 Dynamic model validation-Exciter and Governor Tests

Prior to the dynamic studies, exciter and governor dynamic models were subjected to the following standard controller tests (Exciter open-circuit step response test and Governor mechanical power step response test), and parameter tuning where necessary, to ensure that their dynamic behavior are reasonable and typical for the type of controller or plant

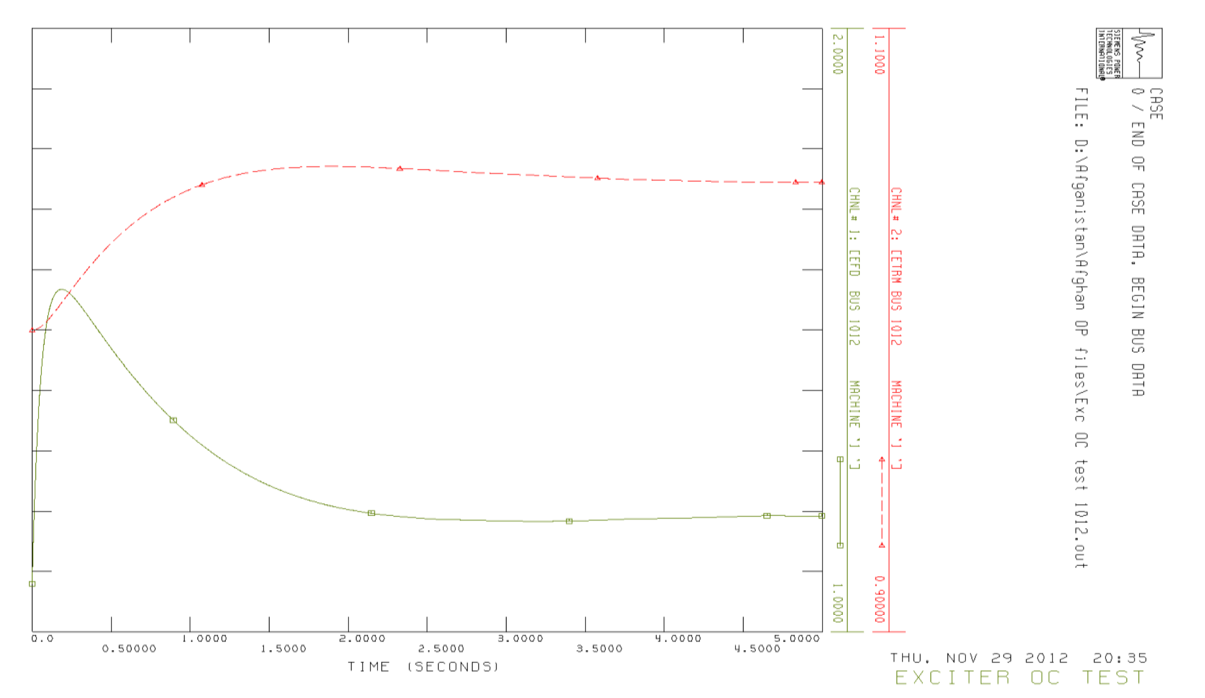


Figure 11.3.6-1: Field and Terminal Voltages -Open Circuit test on representative type of exciters (SEXS)

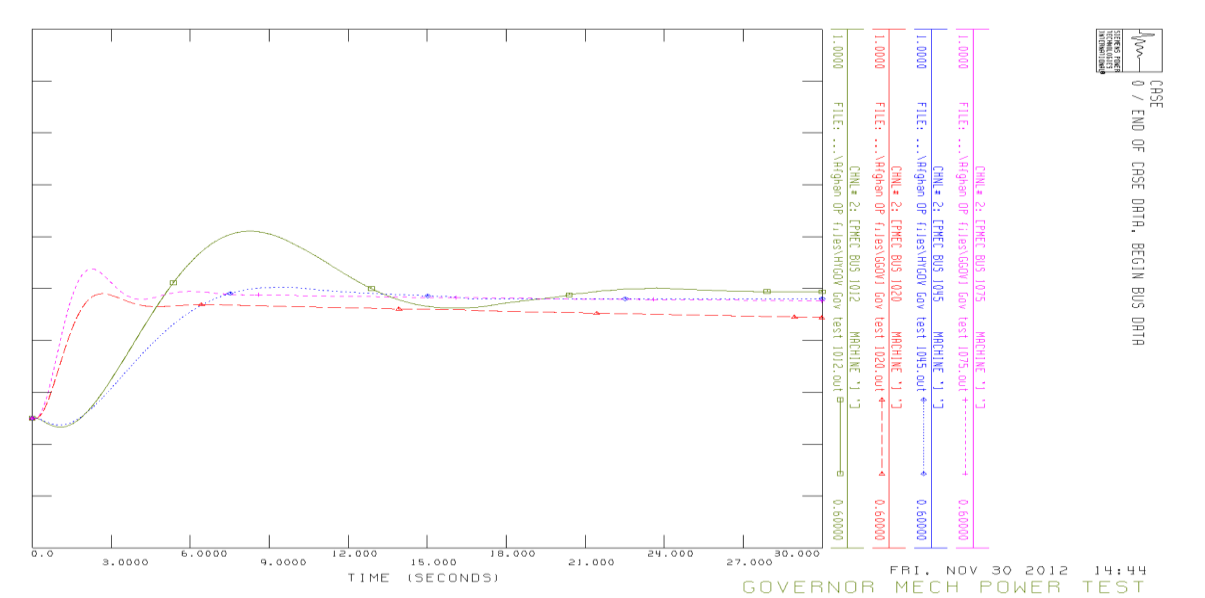


Figure 11.3.6-2: Mech Power -HYGOV & GGOV1 Governor response test

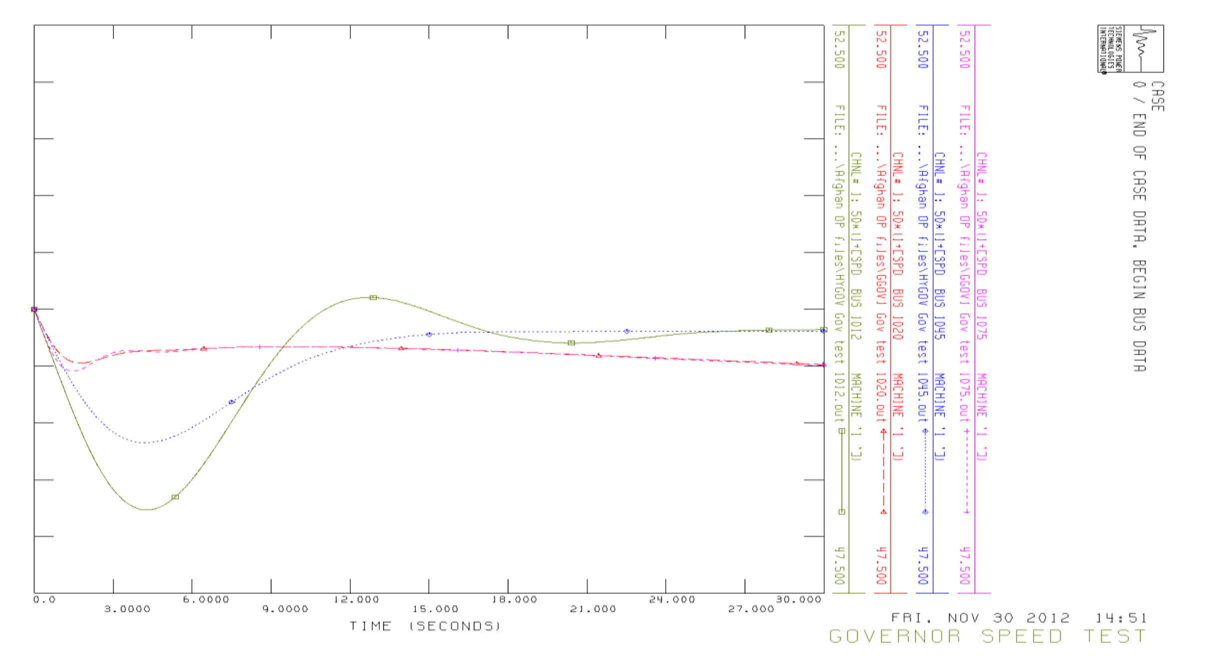


Figure 11.3.6-3: Speed (Hz) - HYGOV & GGOV1 Governor response test

11.3.7 HVDC Back-to-Back models

The dynamic simulations were carried out using the HVDC model CDC7T of the PSS/E standard library. This is a generic model which represents adequately the HVDC link master and converter control and dynamics at both the 1000MW and the 300MW HVDC connections at Pul-e-Chomri substations.

11.3.8 Dynamic Study Cases

Simulations were carried out applying 3-phase faults at critical points of the Afghanistan Power System, as detailed in Table 11.3.8-1Table 11.3.4-1 Stability criteria for the Afghanistan system

This includes faults at:

- 500kV substation at Pul-e-Chomri (Rectifier and Inverter side of the 1000MW HVDC Back-to- Back link)
- 220kV substation at Jalalabad
- 220kV substation at Pul-e-Chomri
- 220kV substation at Naibabad 1 and 2
- 220kV substation at Dehsabz South
- 220kV substation at Arghandi (Dasht-e-Barchi)
- 220kV substation at Noor Jahad
- 110kV Substation at Kabul-NW.

Study cases for 2032

Case	Name	Fault at	Trip circuit
1	F235	Pul-e-Chomri 220kV S/S	220kV line to Doshi, between buses 235-1099
2	F1151	Pul-e-Chomri 500kV S/S	One 500/220kV transformer, between buses 235-1151
3	F1055	Noor Jahad 220kV S/S	220kV line to Qala-i-Naw, between buses 1055-1063
4	F233	Naibabad-1 220kV S/S	220kV line to Mazar-e-Sharif, between buses 230-233
5	F1024	Dehsabz South 220kV S/S	220kV line to Chimtala, between buses 105-1024
6	F1156	Arghandi (Dasht-e-Barchi) 220kV S/S	220kV line to Aynak Copper mine, between buses 1091-1156
7	F118	Kabul North West 110kV S/S	110kV line to Kabul North, between buses 118-120
8	F1037	Jalalabad 220kV S/S	220kV line to Sarobi, between buses 1037-1070
9	F1061	Pul-e-Chomri 500kV S/S	500kV line from Mazar-e-Sharif, between buses 1052-1061
10	F271	Naibabad-2 220kV S/S	220kV line to Pul-e-Chomri, between buses 262-271

Table 11.3.8-1 Study cases

In the transient stability studies the focus was on monitoring & plotting:

- Generator electrical quantities (Electrical Power and Rotor Angles) of the Thermal Power Plants at Tarakkhil and Sheberghan and Hydro Power Plant at Baghdara and Kunar A and B.

- Busbar voltages at 220kV S/S in Naibabad, Pul-e-Chomri, Chimtala and 110kV S/S in Kabul North West

11.3.9 Transient stability study results and graphs

11.3.9.1 Case 1

Case	Name	Fault at	Trip circuit
1	F235	Pul-e-Chomri 220kV S/S	220kV line to Doshi, between buses 235-1099

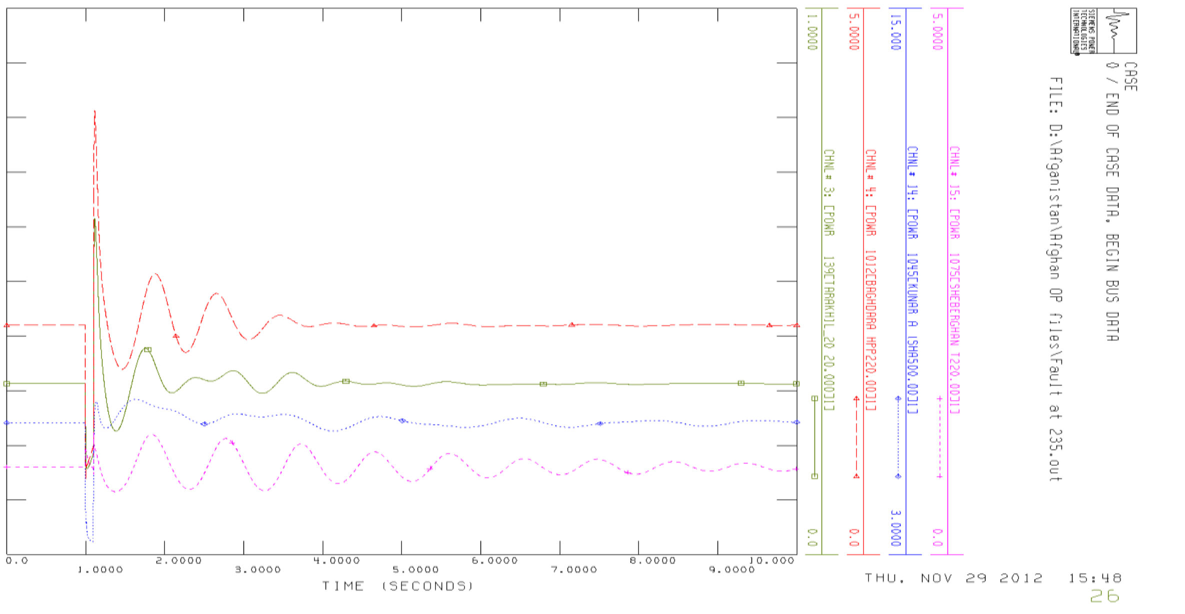


Figure 11.3.9-1: Electrical Power output of machines at Tarakhil, Baghdara, Kunar and Sheberghan

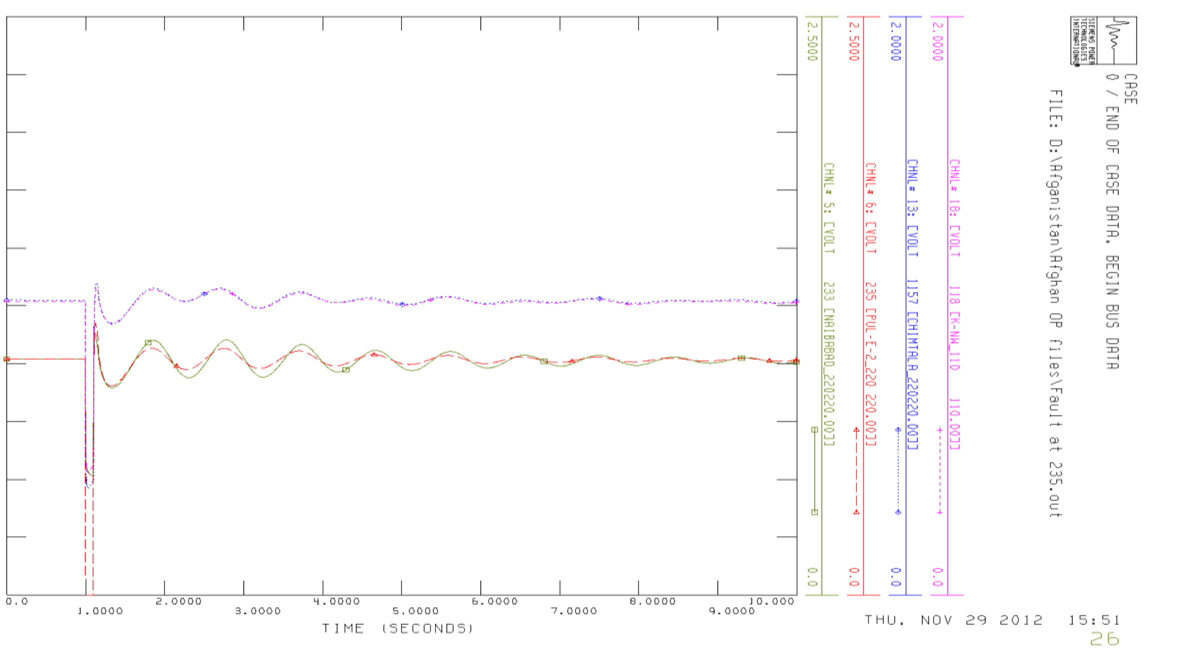


Figure 11.3.9-2: Busbar voltages at 220kV S/S in Naibabad, Pul-e-Comri, Chimtala and 110kV S/S in Kabul North West

11.3.9.2 Case 2

Case	Name	Fault at	Trip circuit
2	F1151	Pul-e-Chomri 500kV S/S	One 500/220kV transformer, between buses 235-1151

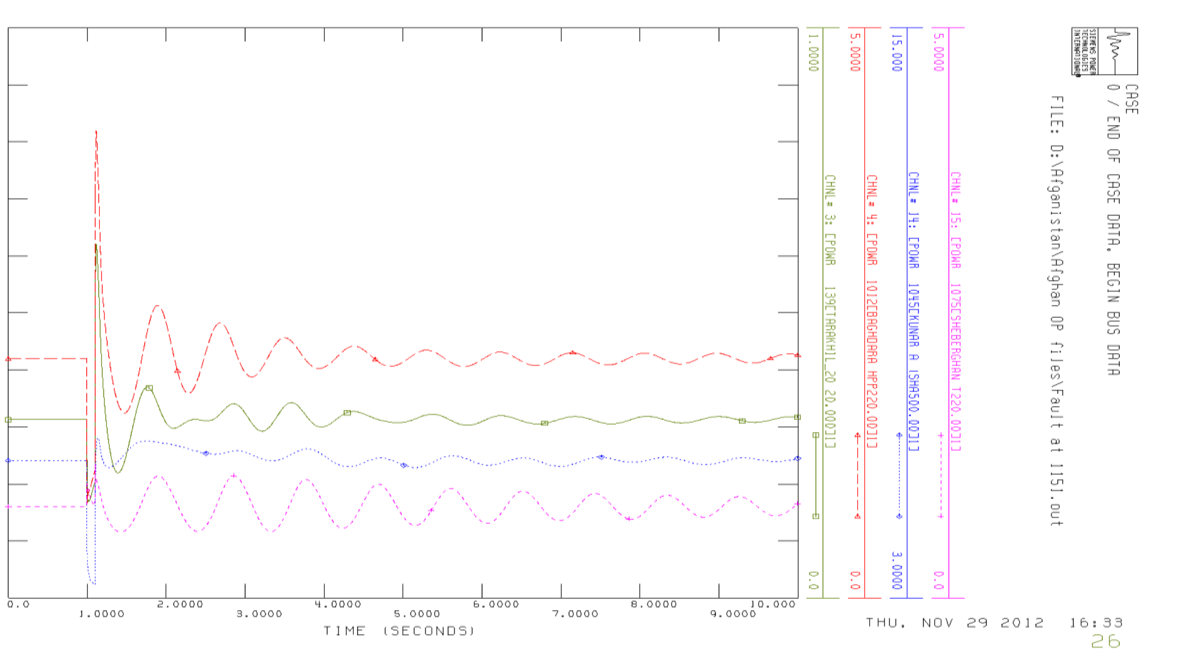


Figure 11.3.9-3: Electrical Power output of machines at Tarakhil, Baghdara, Kunar and Sheberghan

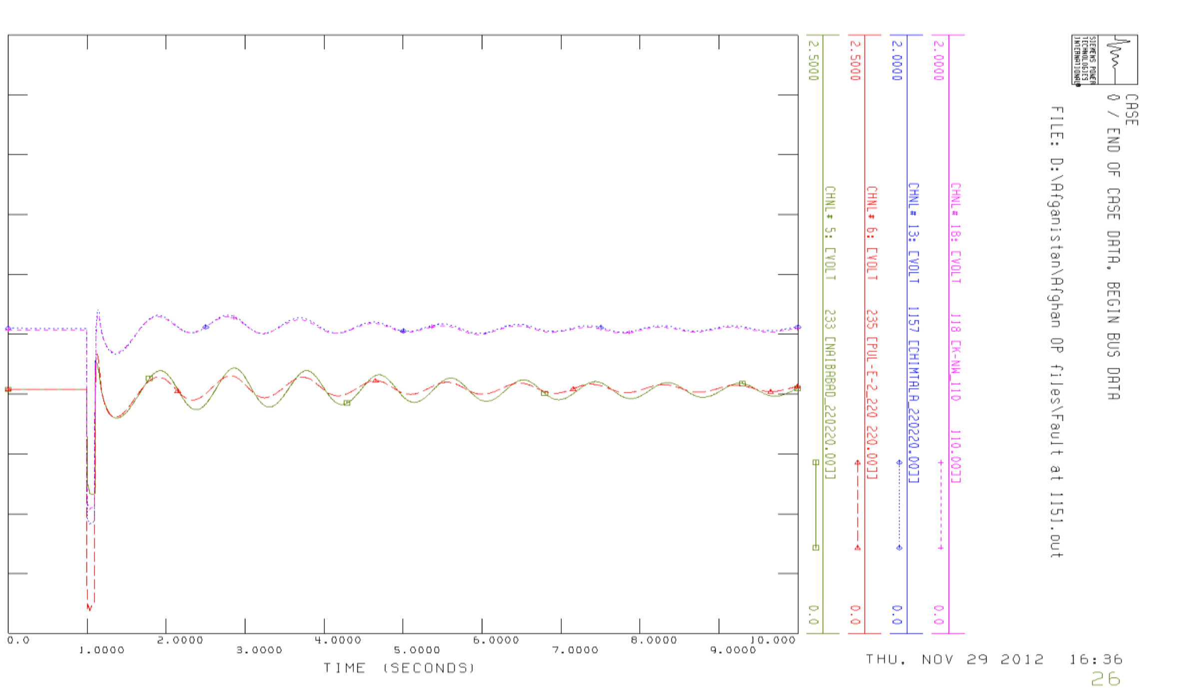


Figure 11.3.9-4: Busbar voltages at 220kV S/S in Naibabad, Pul-e-Comri, Chimtala and 110kV S/S in Kabul North West

11.3.9.3 Case 3

Case	Name	Fault at	Trip circuit
3	F1055	Noor Jahad 220kV S/S	220kV line to Qala-i-Naw, between buses 1055-1063

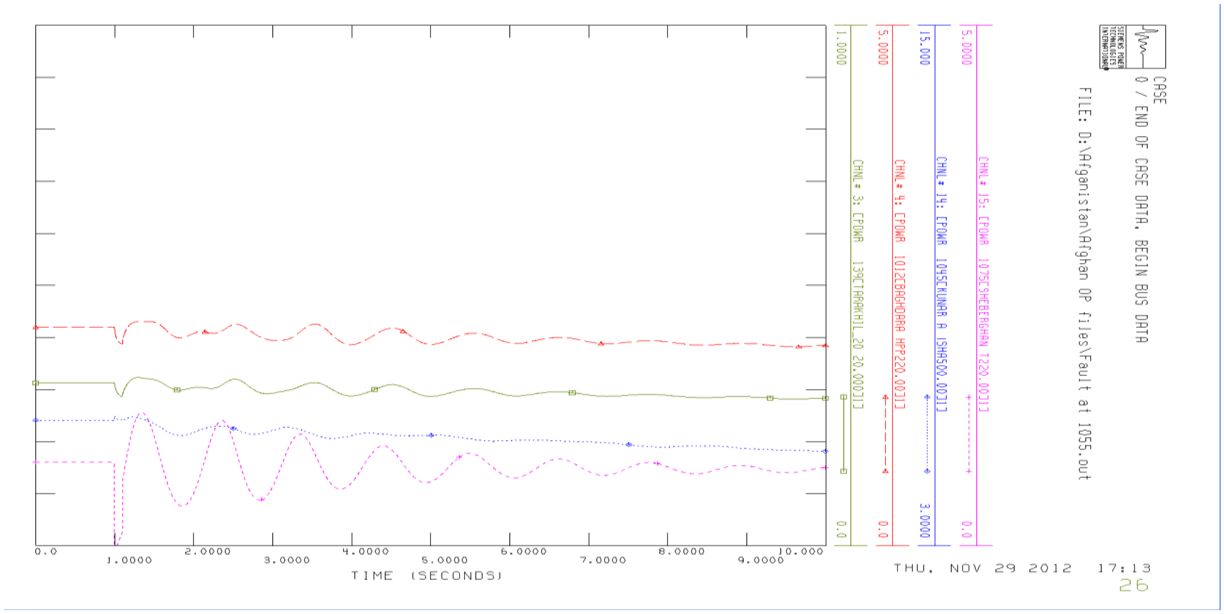


Figure 11.3.9-5: Electrical Power output of machines at Tarakhil, Baghdara, Kunar and Sheberghan

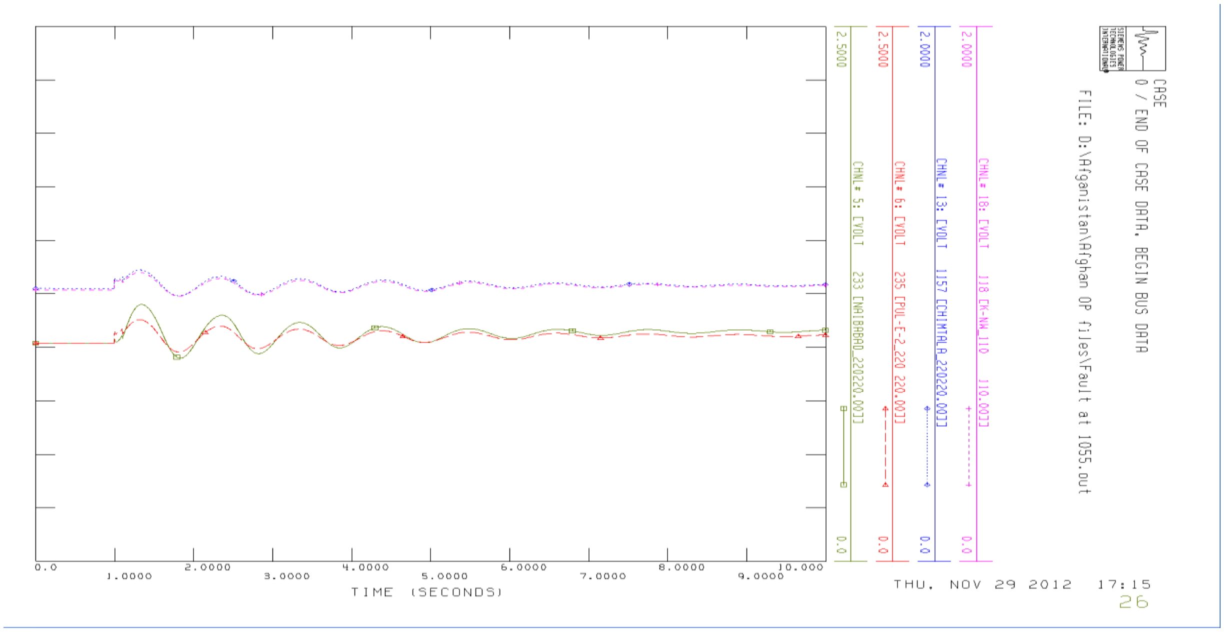


Figure 11.3.9-6: Busbar voltages at 220kV S/S in Naibabad, Pul-e-Comri, Chimtala and 110kV S/S in Kabul North West

11.3.9.4 Case 4

Case	Name	Fault at	Trip circuit
4	F233	Naibabad-1 220kV S/S	220kV line to Mazar-e-Sharif, between buses 230-233

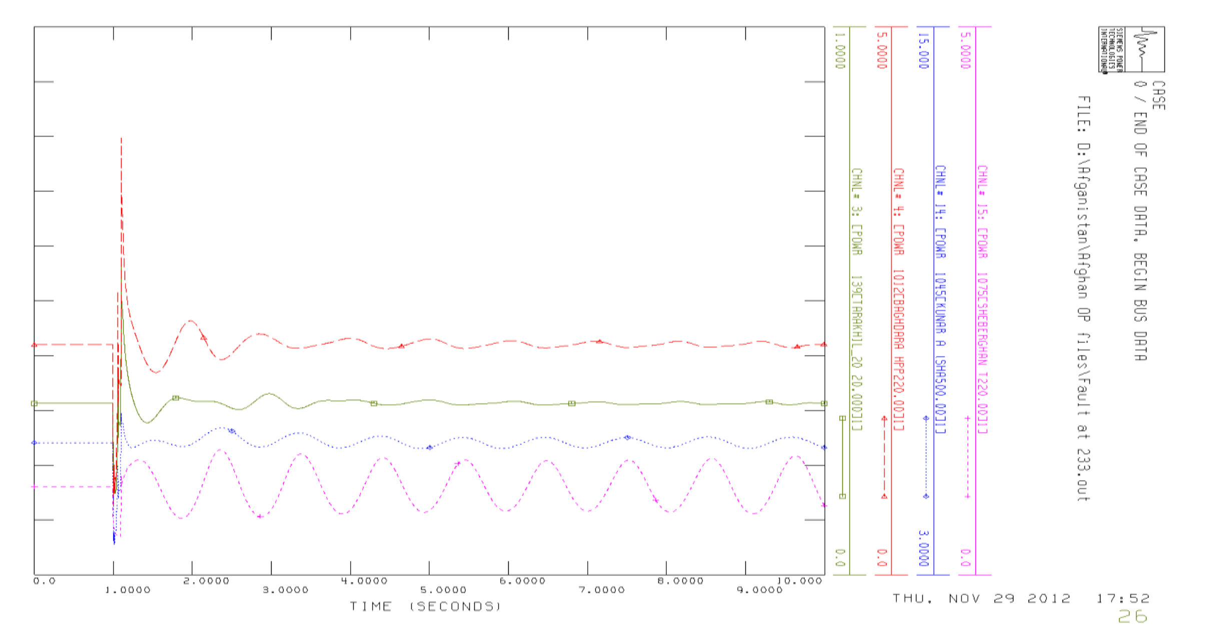


Figure 11.3.9-7: Electrical Power output of machines at Tarakhil, Baghdara, Kunar and Sheberghan

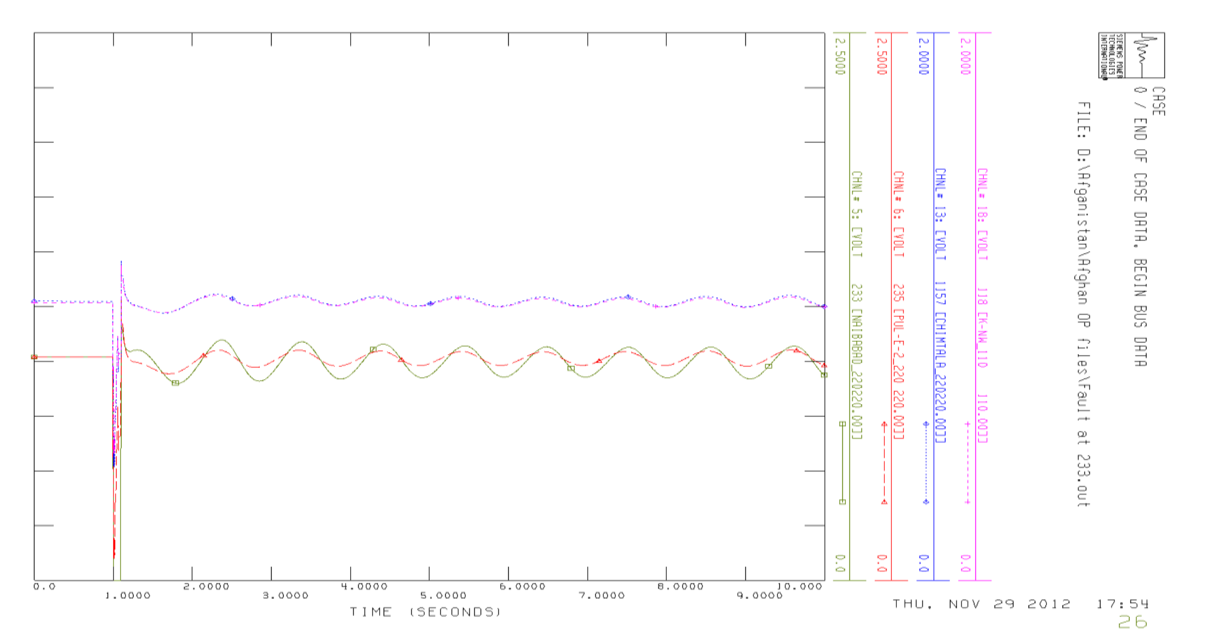


Figure 11.3.9-8: Busbar voltages at 220kV S/S in Naibabad, Pul-e-Comri, Chimtala and 110kV S/S in Kabul North West

11.3.9.5 Case 5

Case	Name	Fault at	Trip circuit
5	F1024	Dehsabz South 220kV S/S	220kV line to Chimtala, between buses 105-1024

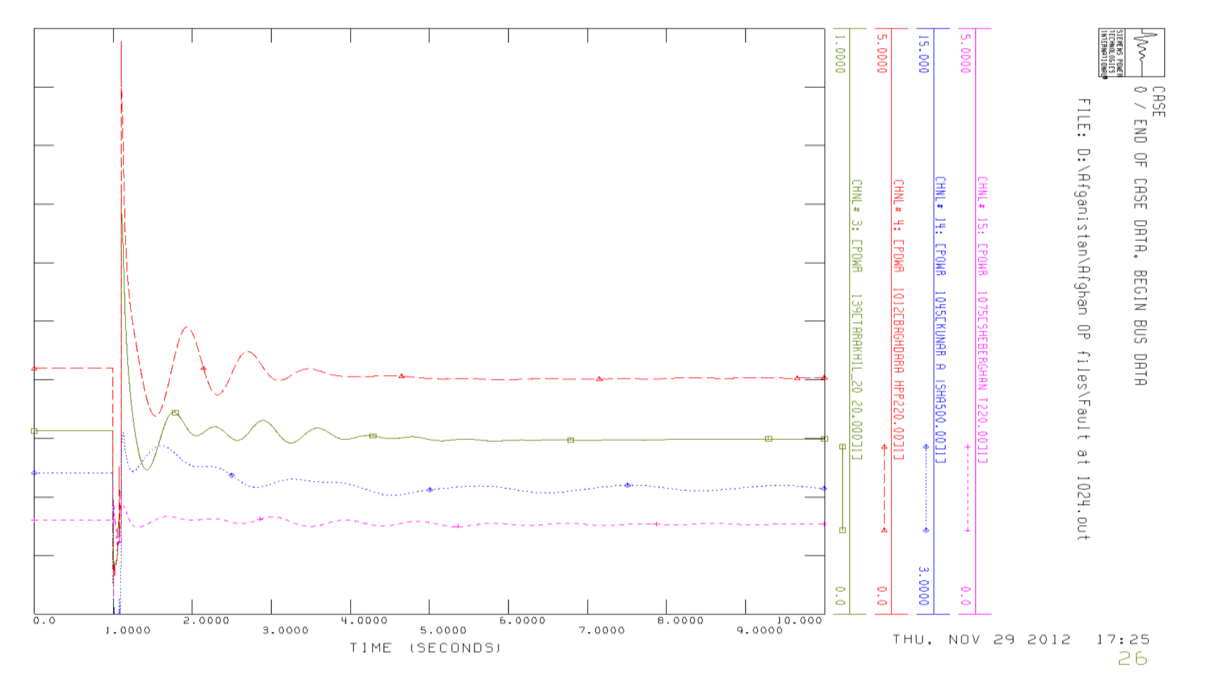


Figure 11.3.9-9: Electrical Power output of machines at Tarakhil, Baghdara, Kunar and Sheberghan

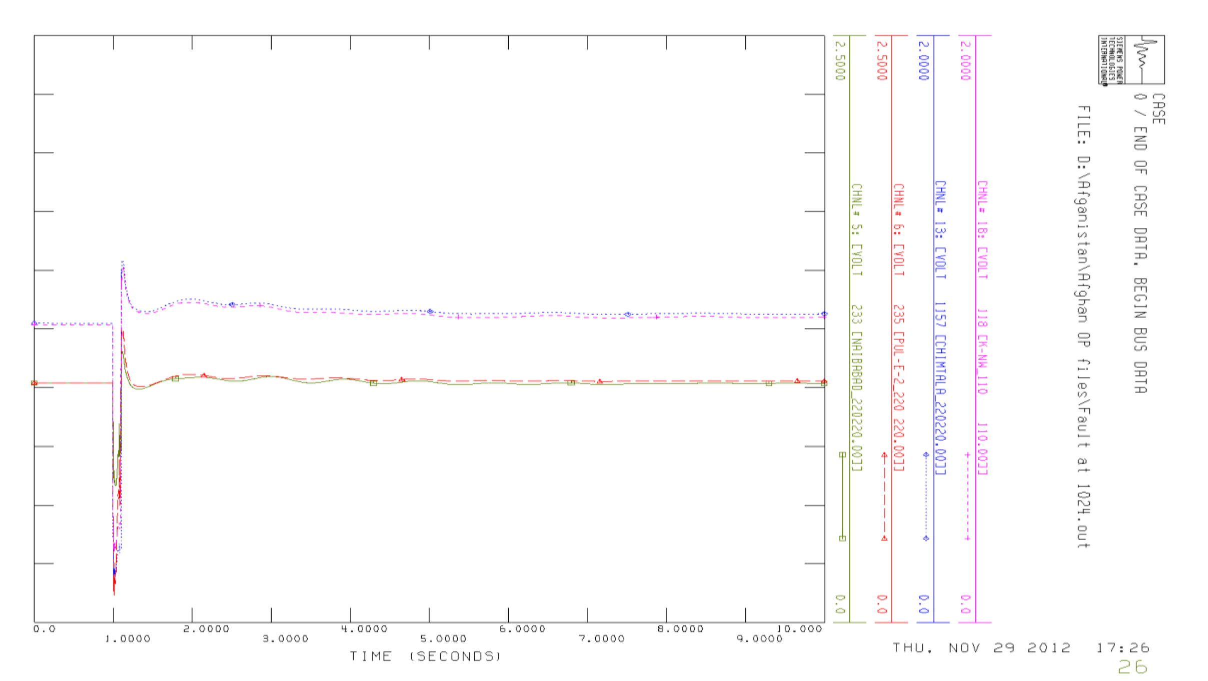


Figure 11.3.9-10: Busbar voltages at 220kV S/S in Naibabad, Pul-e-Comri, Chimtala and 110kV S/S in Kabul North West

11.3.9.6 Case 6

Case	Name	Fault at	Trip circuit
6	F1156	Arghandi 220kV S/S	220kV line to Aynak Copper mine, between buses 1091-1156

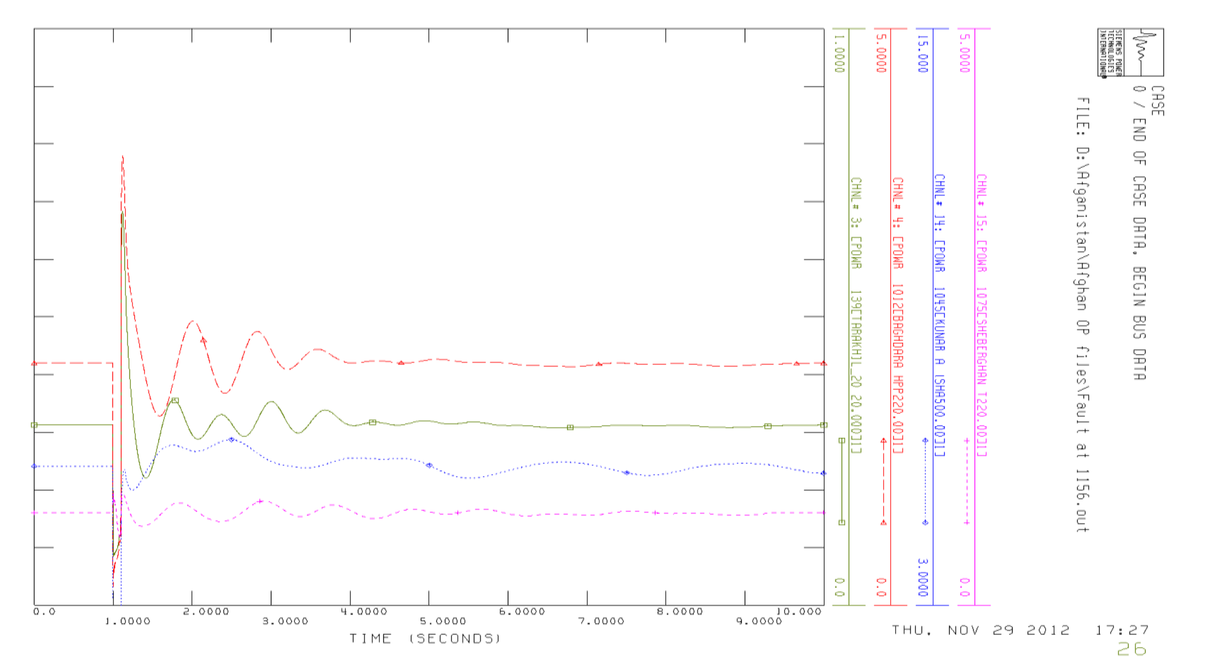


Figure 11.3.9-11: Electrical Power output of machines at Tarakhil, Baghdara, Kunar and Sheberghan

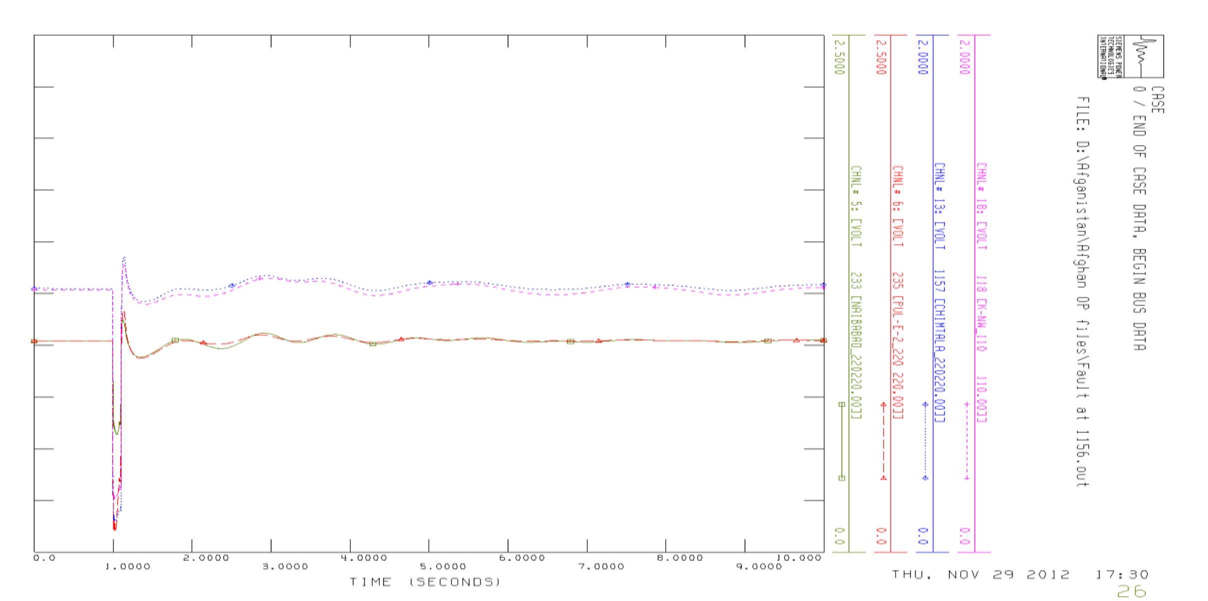


Figure 11.3.9-12: Busbar voltages at 220kV S/S in Naibabad, Pul-e-Comri, Chimtala and 110kV S/S in Kabul North West

11.3.9.7 Case 7

Case	Name	Fault at	Trip circuit
7	F118	Kabul North West 110kV S/S	110kV line to Kabul North, between buses 118-120

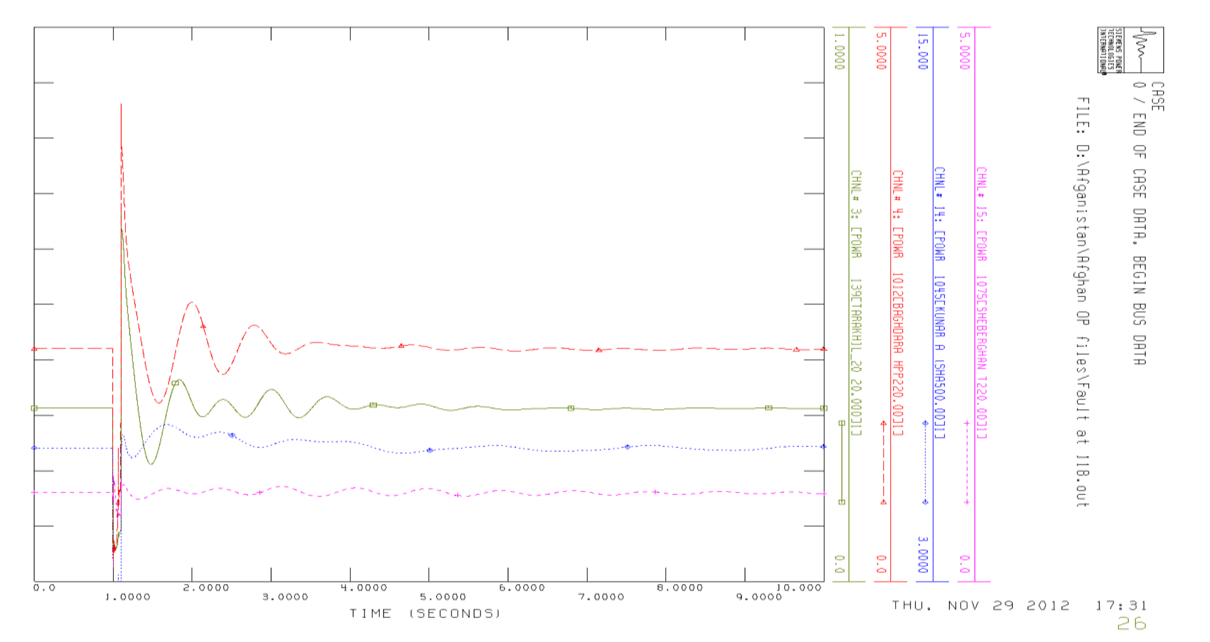


Figure 11.3.9-13: Electrical Power output of machines at Tarakhil, Baghdara, Kunar and Sheberghan

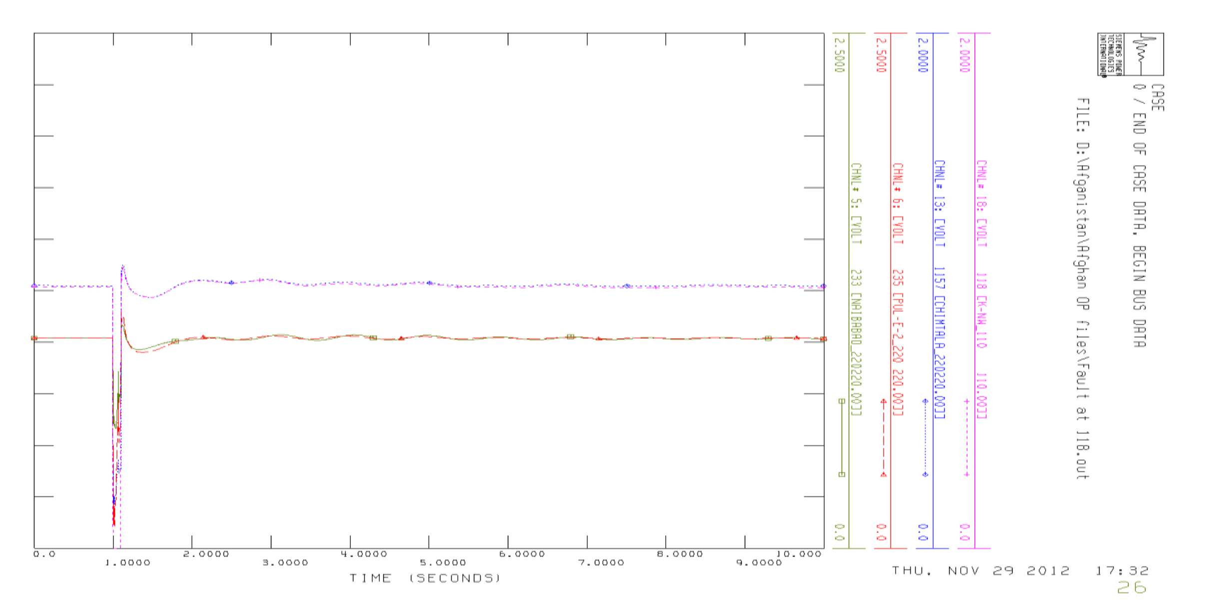


Figure 11.3.9-14: Busbar voltages at 220kV S/S in Naibabad, Pul-e-Comri, Chimtala and 110kV S/S in Kabul North West

11.3.9.8 Case 8

Case	Name	Fault at	Trip circuit
8	F1037	Jalalabad 220kV S/S	2220kV line to Sarobi, between buses 1037-1070

Disturbance too severe, System unstable

11.3.9.9 Case 9

Case	Name	Fault at	Trip circuit
9	F1061	Pul-e-Chomri 500kV S/S	500kV line from Mazar-e-Sharif, between buses 1052-1061

Disturbance too severe, System unstable

11.3.9.10 Case 10

Case	Name	Fault at	Trip circuit
10	F271	Naibabad-2 220kV S/S	220kV line to Pul-e-Chomri, between buses 262-271

Disturbance too severe, System unstable

11.3.10 Summary of study results and conclusions

11.3.10.1 Summary of the results

Table 11.3.10-1 summarizes the results of the simulations carried out

Case	Name	Fault at	Trip circuit	TS assessment
1	F235	Pul-e-Chomri 220kV S/S	220kV line to Doshi, between buses 235-1099	System stable
2	F1151	Pul-e-Chomri 500kV S/S	One 500/220kV transformer, between buses 235-1151	System stable
3	F1055	Noor Jahad 220kV S/S	220kV line to Qala-i-Naw, between buses 1055-1063	System stable
4	F233	Naibabad-1 220kV S/S	220kV line to Mazar-e-Sharif, between buses 230-233	Prolonged oscillations before system returns to stable mode. Tuning of control parameters may be required.
5	F1024	Dehsabz South 220kV S/S	220kV line to Chimtala, between buses 105-1024	System stable
6	F1156	Arghandi (Dasht-e-	220kV line to Aynak Copper	System stable

Case	Name	Fault at	Trip circuit	TS assessment
		Barchi) 220kV S/S	mine, between buses 1091-1156	
7	F118	Kabul North West 110kV S/S	110kV line to Kabul North, between buses 118-120	System stable
8	F1037	Jalalabad 220kV S/S	2220kV line to Sarobi, between buses 1037-1070	Disturbance too severe. System unstable
9	F1061	Pul-e-Chomri 500kV S/S	500kV line from Mazar-e-Sharif, between buses 1052-1061	Disturbance too severe. System unstable
10	F271	Naibabad-2 220kV S/S	220kV line to Pul-e-Chomri, between buses 262-271	Disturbance too severe. System unstable

Table 11.3.10-1 Stability study results and assessment

11.3.10.2 Conclusions

The system remains stable in most of the disturbances studied.
In certain cases however, where a fault is applied at a critical part of the system and involves the loss of the only single circuit supplying bulk power to or from the faulty substation, the system is unstable. In particular:
Cases 9 and 10 are unstable. This is expected due to the severity of the disturbance (loss of the main feeders importing power from Turkmenistan Uzbekistan respectively).
The same applies in case of the loss of the single 500kV line between Pol-e-Chomri and Ishpushta and the loss of the single 220kV line between Jalalabad and Sarobi (case 8). In both cases, reinforcement of the line (e.g. conversion to double circuit) will be necessary and planned accordingly.

Case 4 involves the loss of one (out of the 2) 220 kV circuits between Naibabad and Mazar-e-Sharif. Since these circuits were heavily loaded prior to the fault, this disturbance results in prolonged oscillations before the system returns to a stable mode. Further study will be required to identify the optimum remedial measures and reinforcements that may be needed and/or tuning of machines control parameters at Sheberghan.

11.3.11 Additional study case for 2032-SEPS area

The following additional study cases are focusing at the SEPS system after the NEPS-SEPS interconnection. As a more conservative scenario, it has been assumed that no generation at Kandahar Power Plant (bus 408) is available. Case 11 assumes that a double 220kV circuit is in operation between the Qalat and Kandahar prior to tripping one of the two lines. In case 12 it has also been assumed that one out of the two 220kV lines between buses 1088 (Qalat) and1089 (Kandahar) is out of operation prior to applying a 3ph fault at Qalat and tripping the second 220kV line.

Additional Study case for 2032

Case	Name	Fault at	Trip circuit
11	F1088a	Qalat 220kV S/S	One of the two 220kV lines to Kandahar, between buses 1088 (Qalat) -1089 (Kandahar), assuming the other one is in operation
12	F1088b	Qalat 220kV S/S	One of the two 220kV lines to Kandahar, between buses 1088 (Qalat) -1089 (Kandahar), assuming the other one is already out of service or not available
13	F406	Duraij 110kV bus	110kV line between buses 406 (Duraij)-1118 (Maiwand)

Table 11.3.11-1 Additional Study cases for SEPS

In the transient stability studies the focus was on monitoring & plotting:

- Generator electrical quantities (Electrical Power and Rotor Angles) of the Thermal Power Plants at Tarakkhil and Sheberghan and Hydro Power Plant at Baghdara and Kunar A and B. Also the generator buses at Kajakai and Olambagh

- Busbar voltages at 220kV S/S in Naibabad, Pul-e-Chomri, Chimtala and 110kV S/S in Kabul North West. Also bus voltages at 110kV Kajakai, 20kV Kajakai, 110kV Olambagh HPP, and 110kV Kandahar

11.3.12 Transient stability study results and graphs

11.3.12.1 Case 11

Case	Name	Fault at	Trip circuit
11	F1088a	Qalat 220kV S/S	One of the two 220kV lines to Kandahar, between buses 1088 (Qalat) -1089 (Kandahar), assuming the other one is in operation

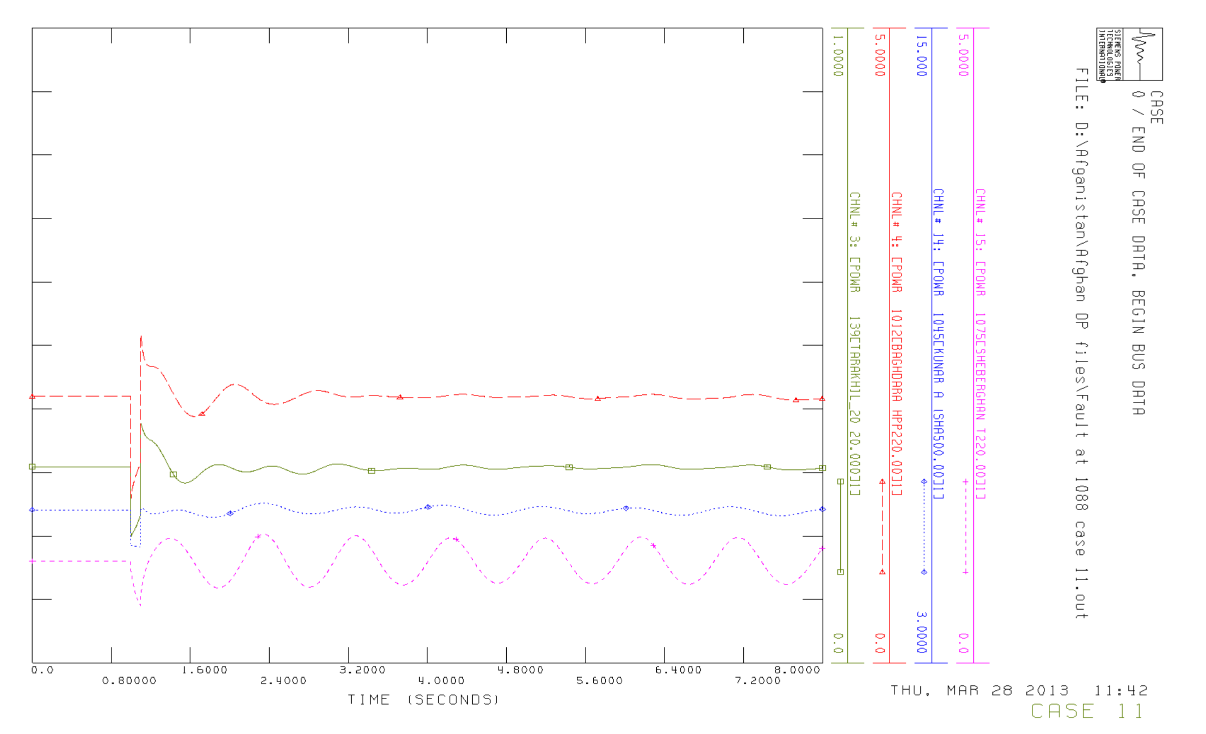


Figure 11.3.12-1: Electrical Power output of generators at Tarakhil, Baghdara, Kunar and Sheberghan

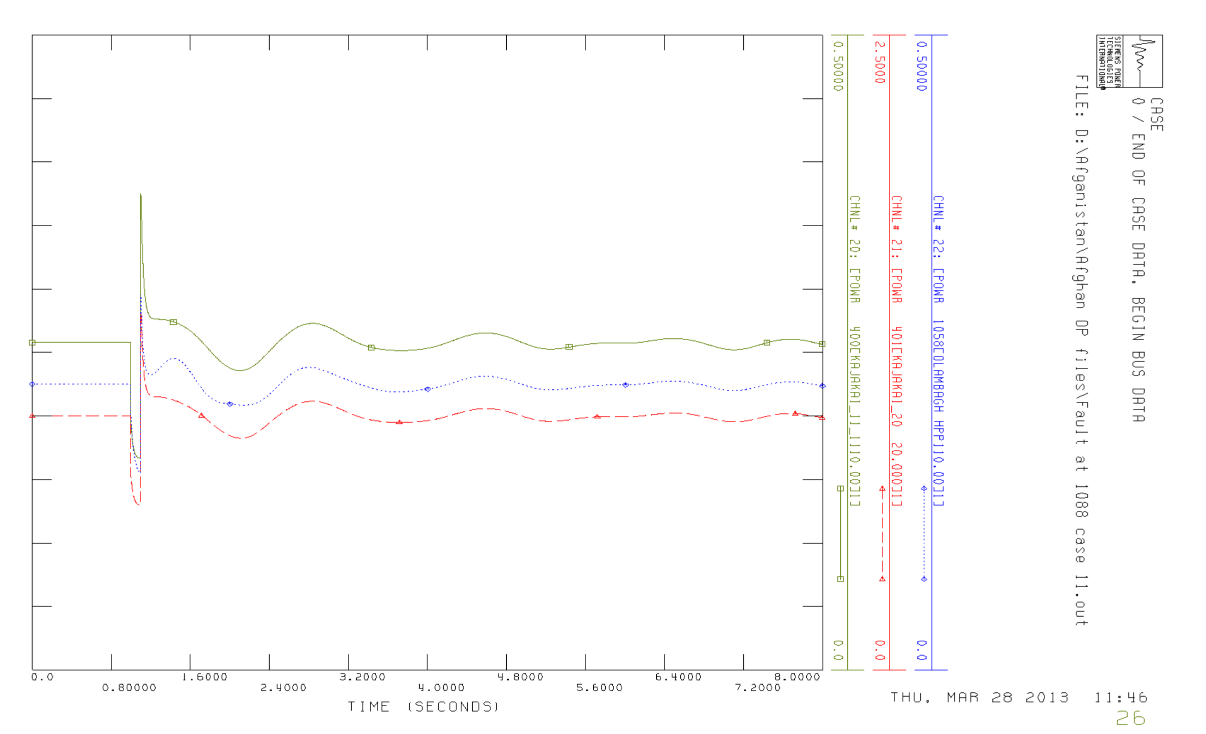


Figure 11.3.12-2: Electrical Power output of generators at Kajakai and Olambagh

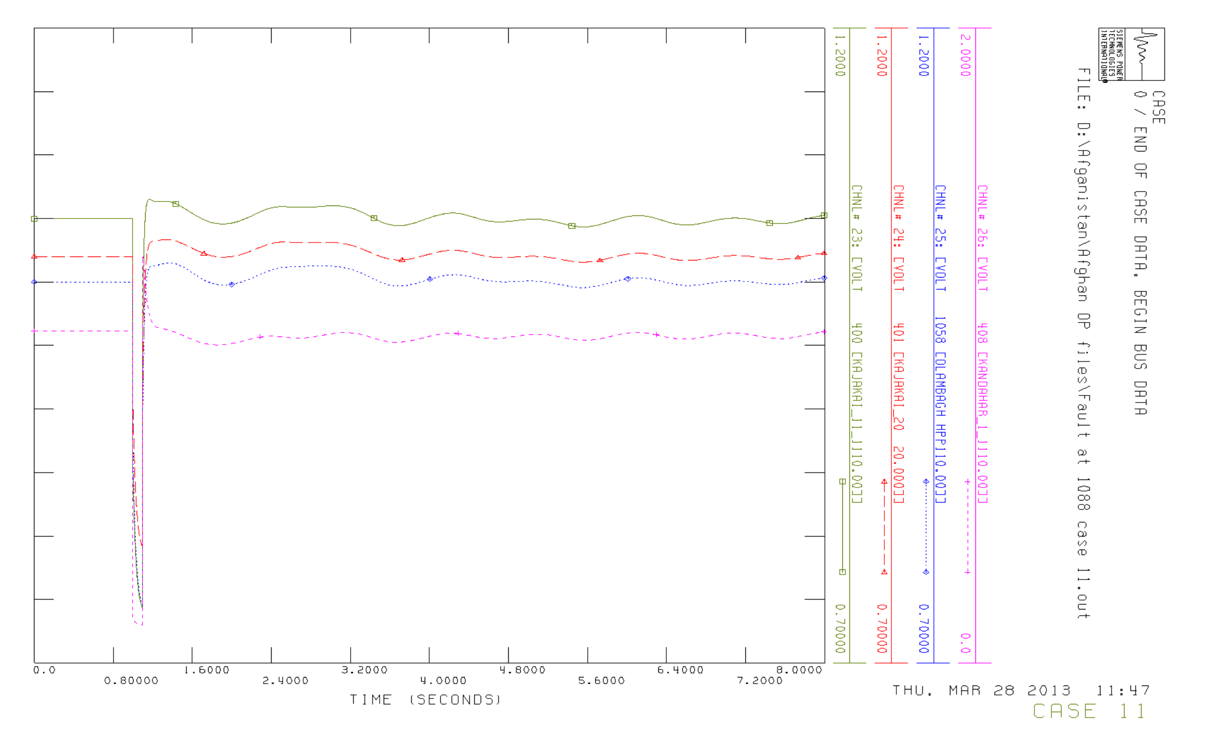


Figure 11.3.12-3: Busbar voltages at 110kV Kajakai, 20kV Kajakai, 110kV Olambagh HPP, and 110kV Kandahar

11.3.12.2 Case 12

Case	Name	Fault at	Trip circuit
12	F1088b	Qalat 220kV S/S	One of the two 220kV lines to Kandahar, between buses 1088 (Qalat) -1089 (Kandahar), assuming the other one is already out of service or not in operation

The total generation at SEPS under this scenario, with Kandahar PP out of service, is 174MW. (Kajakai HPP: 152MW, Olambagh HPP: 22 MW)

The total load at SEPS is assumed 294 MW. Therefore upon separation of the SEPS system, following the tripping of the second 220kV line between Qalat -Kandahar, the power unbalance will lead to voltage collapse at some SEPS buses, particularly at Kandahar 110kV S/S, as shown on the dynamic plot below:

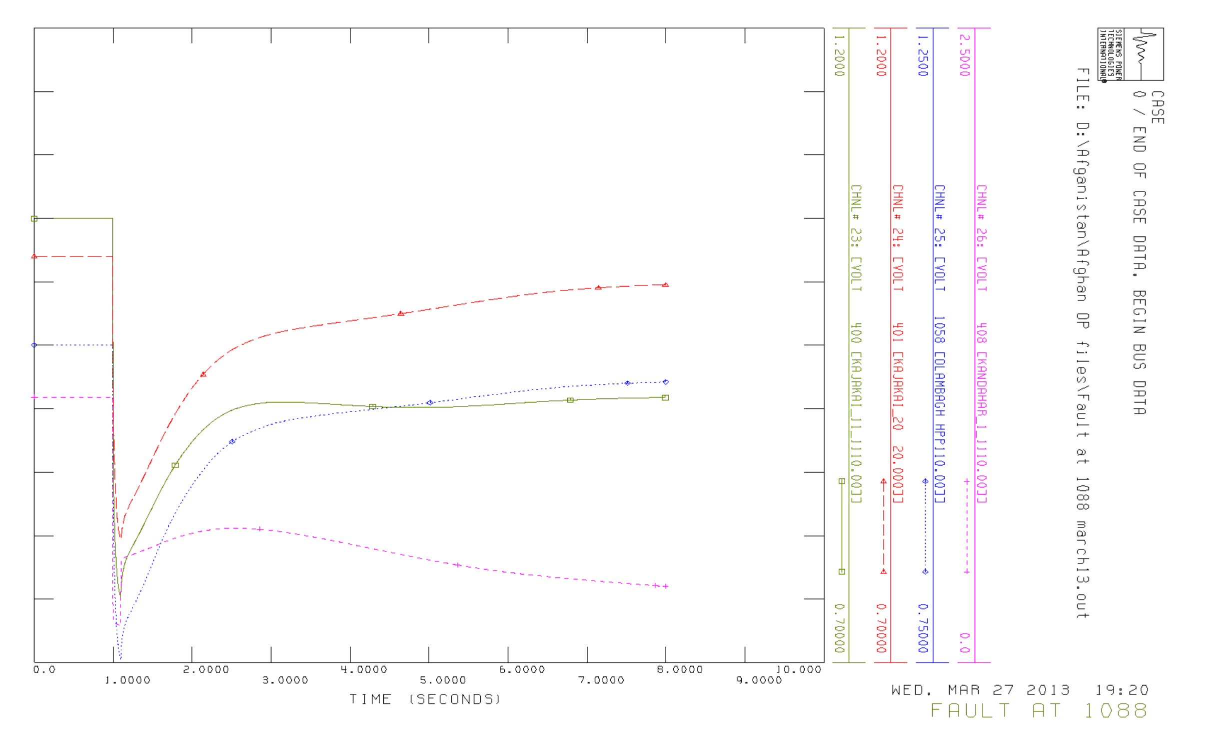


Figure 11.3.12-4: Busbar voltages at 110kV Kajakai, 20kV Kajakai, 110kV Olambagh HPP and 110kV Kandahar

Under this conditions, either load will have to be reduced or generation to be increased at SEPS area. Reducing load to approx 170MW, all bus voltages recover and the generators return to stable mode after the disturbance, as shown on the following graphs.

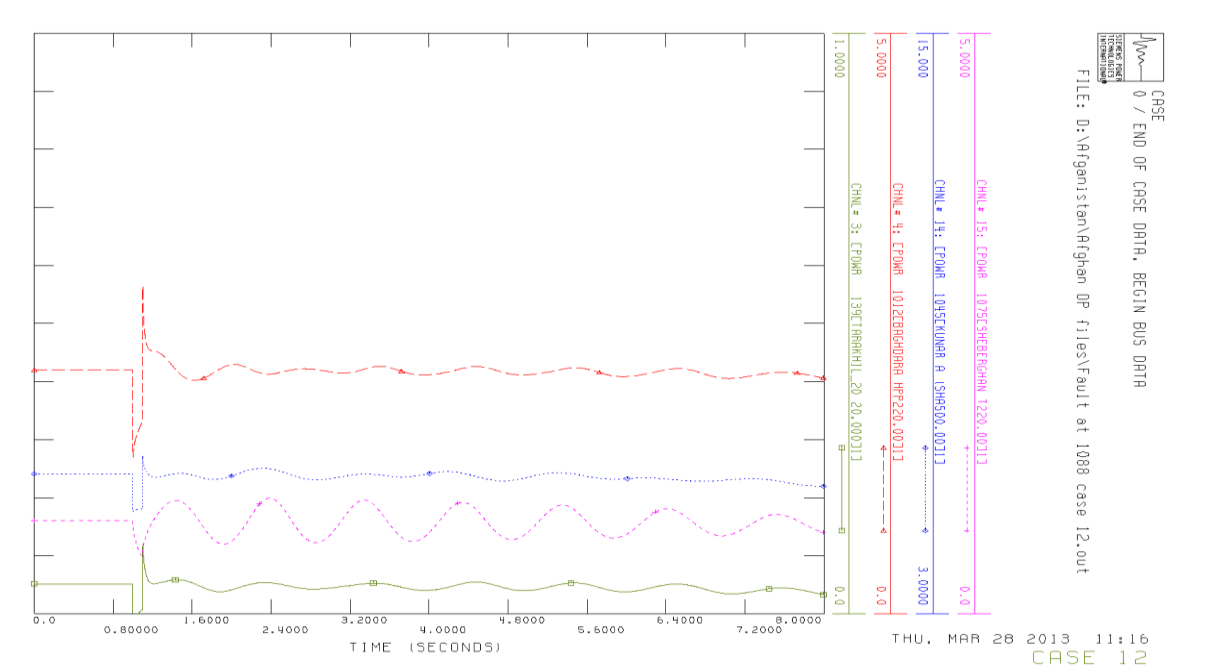


Figure 11.3.12-5: Electrical Power output of generators at Tarakhil, Baghdara, Kunar and Sheberghan

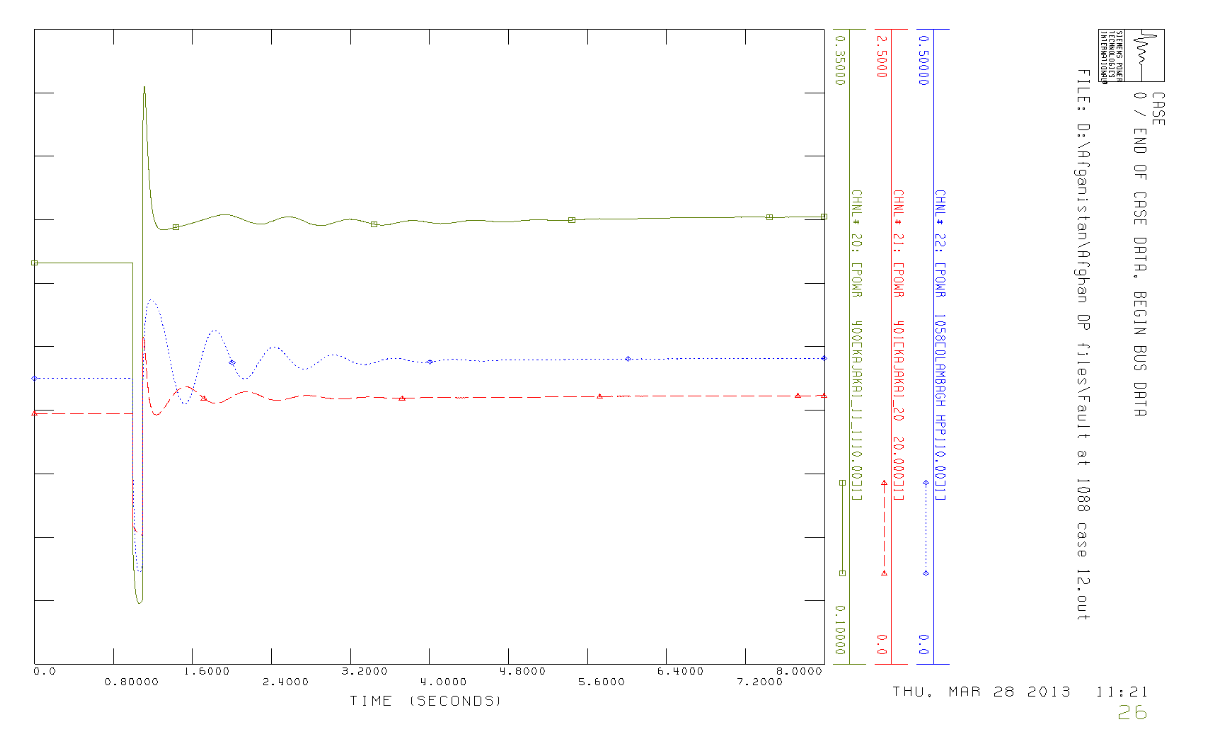


Figure 11.3.12-6: Electrical Power output of generators at Kajakai and Olambagh

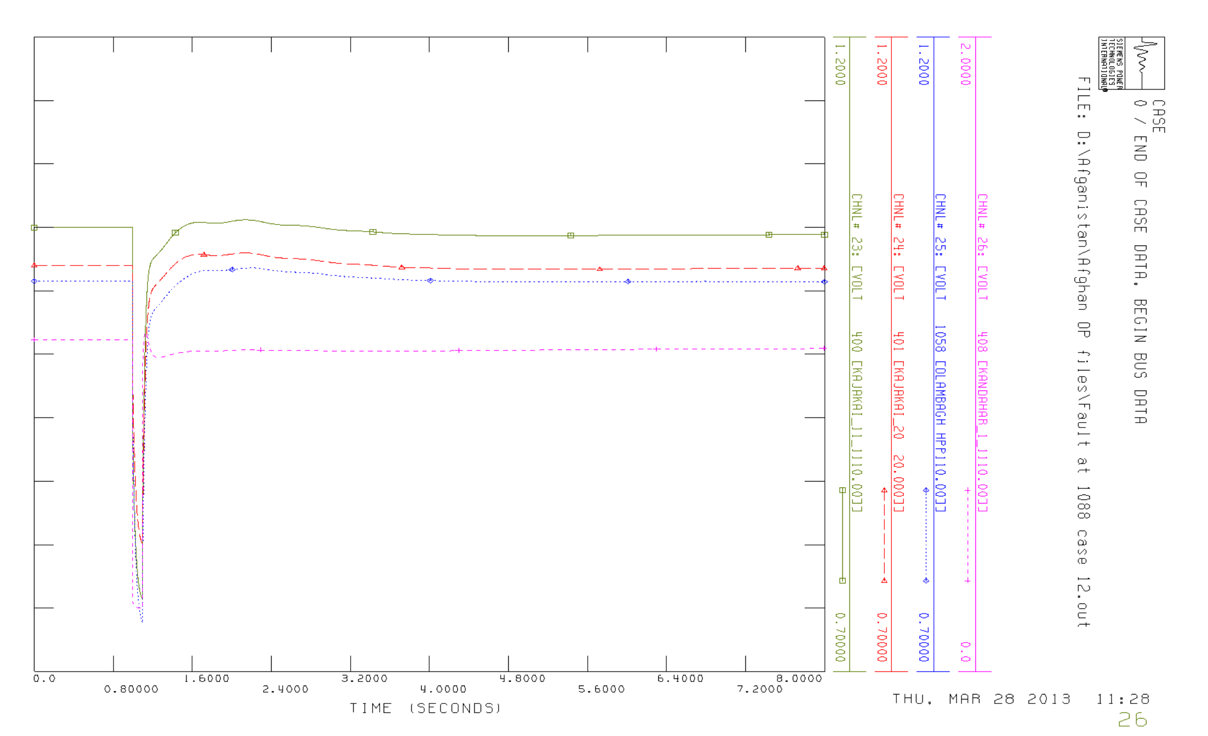


Figure 11.3.12-7: Busbar voltages at 110kV Kajakai, 20kV Kajakai, 110kV Olambagh HPP, and 110kV Kandahar

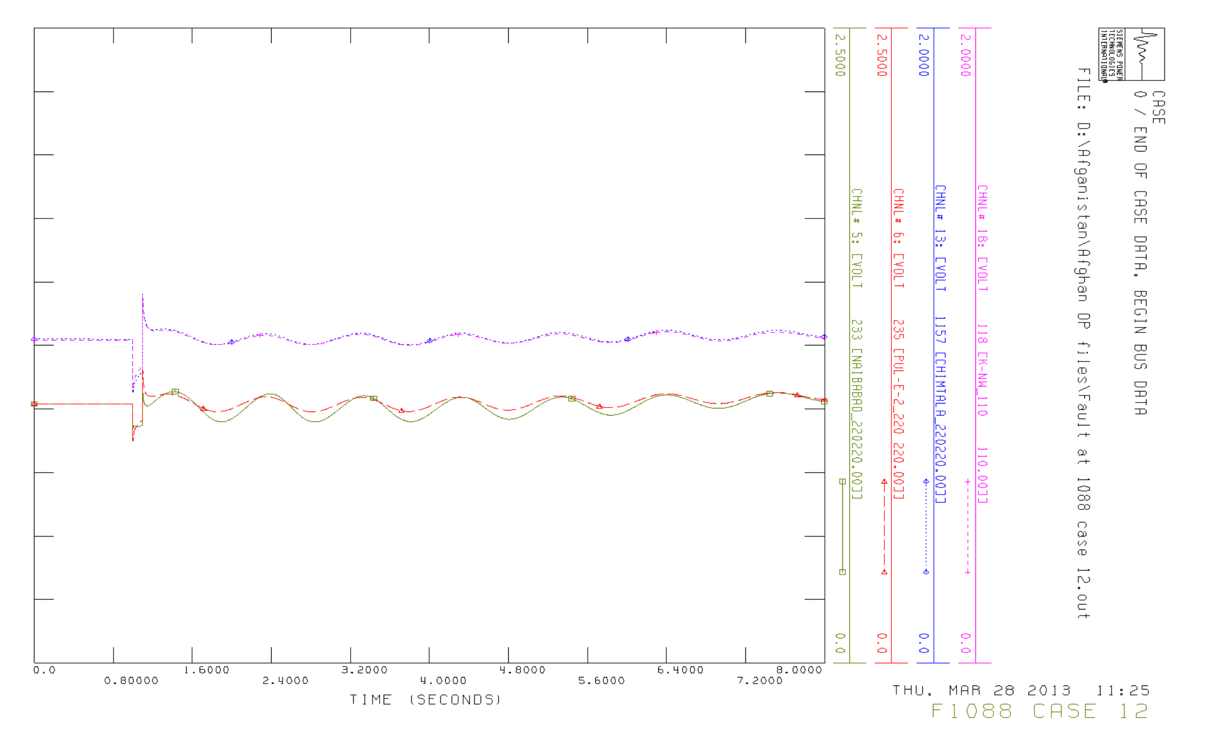


Figure 11.3.12-8: Busbar voltages at 220kV S/S in Naibabad, Pul-e-Comri, Chimtala and 110kV S/S in Kabul North West

11.3.12.3 Case 13

Case	Name	Fault at	Trip circuit
13	F406	Duraij 110kV bus	110kV line between buses 406 (Duraij)-1118 (Maiwand)

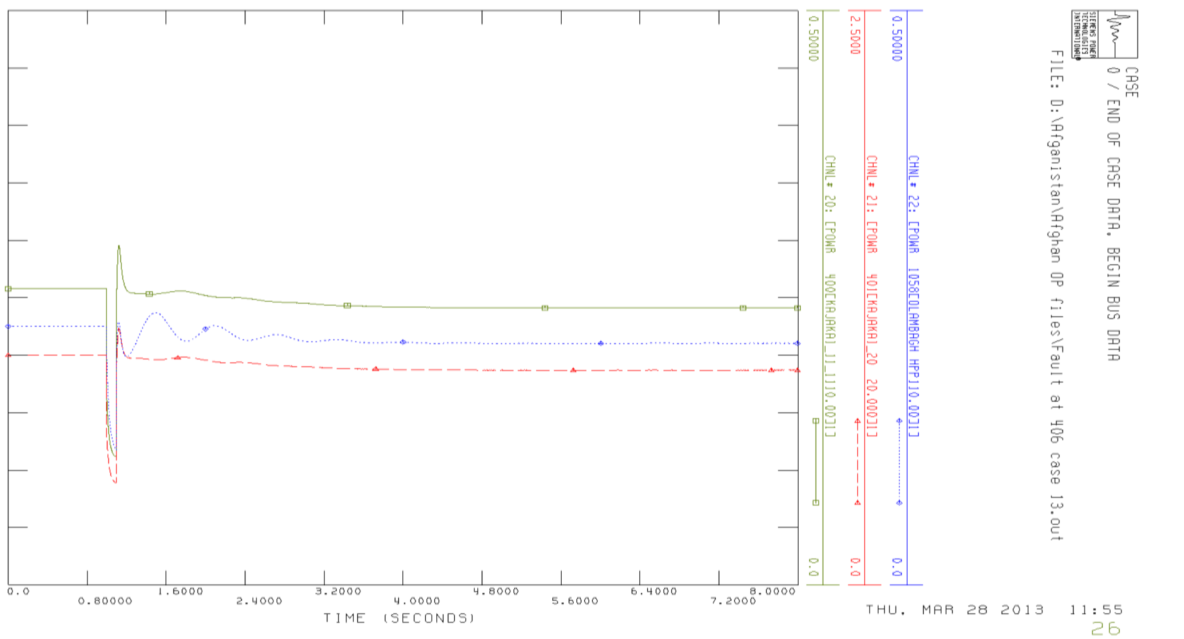


Figure 11.3.12-9: Electrical Power output of generators at Kajakai and Olambagh

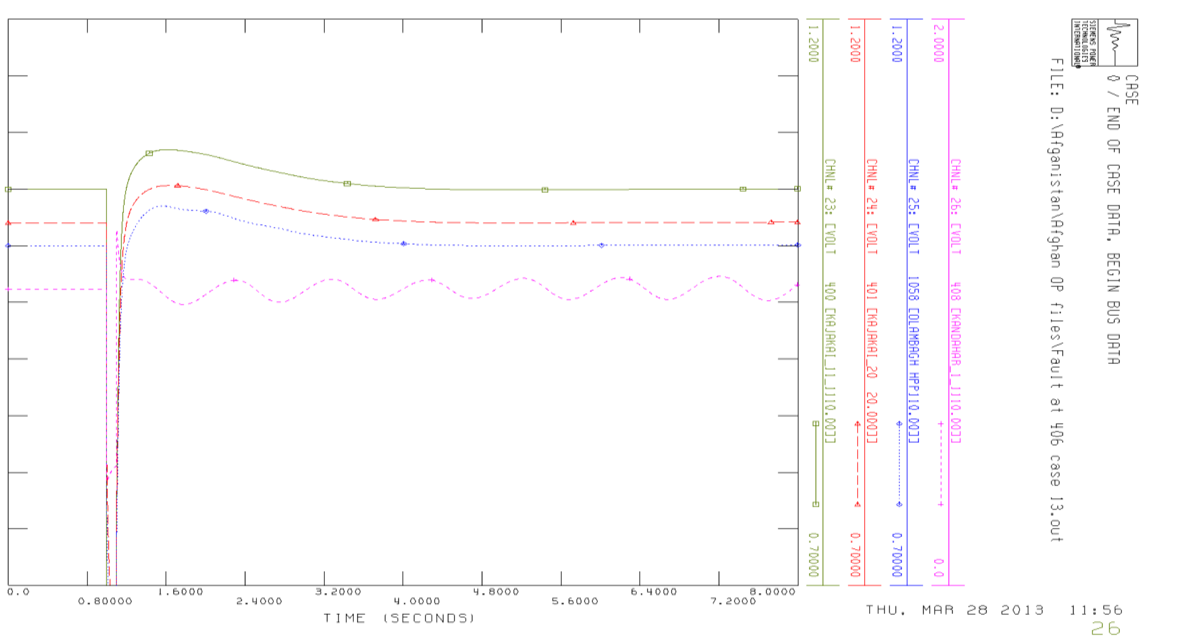


Figure 11.3.12-10: Busbar voltages at 110kV Kajakai, 20kV Kajakai, 110kV Olambagh HPP, and 110kV Kandahar

11.3.13 Summary of study results and conclusions

11.3.13.1 Summary of the results

Table 11.3.10-1 summarizes the results of the additional simulations carried out

Case	Name	Fault at	Trip circuit	TS assessment
11	F1088a	Qalat 220kV S/S	Trip one of the two 220kV lines to Kandahar, between buses 1088 (Qalat) -1089 (Kandahar), assuming the other one is in operation	System stable
12	F1088b	Qalat 220kV S/S	One of the two 220kV lines to Kandahar, between buses 1088 (Qalat) -1089 (Kandahar), assuming the other one is already out of service/operation	This case, entails tripping the SEPS-NEPS interconnection, leading to islanding of the SEPS area. System stable if load at SEPS is reduced or generation increased, to maintain power balance at SEPS
13	F406	Duraij 110kV bus	110kV line between buses 406 (Duraij)-1118 (Maiwand)	System stable

Table 11.3.13-1 Stability study results and assessment

11.3.13.2 Conclusions

The system remains stable for the the disturbances studied. Case 12, entails tripping the SEPS-NEPS interconnection, leading to islanding of the SEPS area. System will be stable if load at SEPS is reduced or generation increased (i.e. at Kandahar) , to maintain power balance within the SEPS area. As stated previously, in cases of some small oscillations are observed, further study will be required to identify the optimum remedial measures and reinforcements that may be needed and/or tuning of generator control parameters.

12. Power Sector Development Plan

12.1 Generation and Transmission expansion

For the development of the power sector within Afghanistan the available sources of power, the forecasted demand development and the requirements and constraints for the transmission system have been considered within the optimization process, which necessitates the use of both national resources as well as imports to cover the load growth expected according to the base case load scenario. In view of the increasing national generation and imports to cover the demand growth, the implementation of major transmission projects is required. Furthermore increasing of the area to be supplied by the national grid has to be promoted by implementing transmission projects within the several provinces of Afghanistan.

The measures for generation expansion, major transmission reinforcement and transmission network development within the provinces have to be taken in parallel. In addition to the projects discussed in this master plan, construction and expansions of the distribution system have also to be considered.

According to the results of the optimization study, the following projects are considered as high ranked and the process for their implementation phase must be expedited immediate, if power shortages are to be avoided.

- development of Sheberghan TPP with 200 MW
- finalizing Salma HPP and Kajaki Expansion HPP
- new Turkmenistan to Afghanistan interconnector stage A
- additional Hindu Kush crossing stage A
- new Turkmenistan to Afghanistan interconnector stage B
- NEPS to SEPS interconnector stage A
- investment within the provinces stage A.

In order to reach high connection rate and to achieve the goal of providing power supply for the whole Afghanistan investment as mentioned in the tables below for all the sub-areas generation expansion, transmission reinforcement and development within the provinces has to be taken. This will need a total investment of $10.096m, $7.330m for generation development and network integration, $1.727m for major transmission projects and reactive power compensation and $1.040m for transmission network development within the provinces up to the year 2032.

The development for the different projects was structured in stages according to the load development within the provinces, the optimized generation expansion and usage of import options and the implementation of major transmission projects.
Stage A comprise the short term up to 2015 and stage B covers the development up to 2020. Long term development is considered in stage C up to 2025 and stage D up to 2032.

The following tables summarize the proposed projects and stages of the project development, as discussed in the previous chapters for the optimized development scenario.

Table 12.1-1 below shows the investment required for the network expansion within the development stages.

Network expansion for supply within the Provinces		Investment [m$]				
		Subtotal by Province	Stage A	Stage B	Stage C	Stage D
P_01	Province Badakhshan	59.7	56.1		3.7	
P_02	Province Badghis	22.9		11.4	7.7	3.9
P_03	Province Baghlan	23.8	14.6	2.5	6.8	
P_04	Province Balkh	21.2	19.3	1.9		
P_05	Province Bamyan	41.5		41.5		
P_06	Province Daykundi	24.2				24.2
P_05	Province Farah	0.0				
P_08	Province Faryab	38.3	9.0	28.6		0.7
P_09	Province Ghazni	38.8		31.5	1.2	6.0
P_10	Province Ghor	63.2		53.2		10.0
P_11	Province Helmand	18.7	8.4	1.7	8.6	
P_12	Province Herat	77.8	18.3	15.3	28.8	15.3
P_13	Province Jowzjan	12.1	11.0	1.1		
P_14	Province Kabul	135.3	60.3	27.0	39.4	8.6
P_15	Province Kandahar	14.2	4.9	1.6	3.3	4.4
P_16	Province Kapisa	25.9		23.7	2.2	
P_17	Province Khost	19.8		18.1	0.9	0.9
P_18	Province Kunar	16.1		14.4	0.9	0.9
P_19	Province Kunduz	40.9	25.6	8.5	6.8	
P_20	Province Laghman	1.7			0.9	0.9
P_21	Province Logar	19.1		17.6		1.6
P_22	Province Nangarhar	45.2		1.7	35.1	8.3
P_23	Province Nimruz	34.9			34.9	
P_24	Province Nuristan	0.0				
P_25	Province Paktia	18.2		17.0		1.2
P_26	Province Paktika	19.7		18.2		1.5
P_27	Province Panjshir	12.8		10.9	0.6	1.2
P_28	Province Parwan	18.1	8.5	7.2	2.5	
P_29	Province Samangan	9.5	7.6	0.7	1.2	
P_30	Province Sar-e Pol	33.3	10.6	21.3		1.4
P_31	Province Takhar	67.7	30.0	17.9	18.9	0.9
P_32	Province Uruzgan	34.9		26.1	8.8	
P_33	Province Wardak	15.9	6.1	7.7	0.9	1.2
P_34	Province Zabul	14.4		11.5	0.9	2.0
	Total	1040.1	290.1	439.8	215.1	95.0

Table 12.1-1: Stages and investment of network expansion for supply within the Provinces

The detailed breakdown of the investments required within the provinces over the years is given in **Annex 12.1-1**.

Table 12.1-2 and 12.1.-3 indicates the investment estimated for development of the generation projects according to the optimized expansion scenario as well as the investment estimated for the major transmission network development projects.

Generation expansion project		Investment power plant plus networkintegration[m$]				
		Subtotal by project	Stage A	Stage B	Stage C	Stage D
G_01	Salma HPP	236.6	236.6			
G_02	Kajaki Expansion HPP	91.1	91.1			
G_21	Sheberghan TPP 2x200MW	697.0		348.5	348.5	
G_10	Kunar B HPP	633.0			633.0	
G_05	Kunar A HPP	2086.8				2086.8
G_22	Ishpushta TPP 400MW	761.1				761.1
G_06	Kajaki Addition HPP	314.8				314.8
G_23	Dara-i-Suf TPP 800MW	1484.2				1484.2
G_12	Olambagh HPP	410.3				410.3
G_03	Baghdara HPP	614.8				614.8
	Total	7329.6	327.6	348.5	981.5	5671.9

Table 12.1-2: Stages and investment for power generation expansion optimized scenario

Major transmission project		Investment [m$]				
		Subtotal by project	Stage A	Stage B	Stage C	Stage D
T_01	TKM-AFG interconnector	843.0	106.5	535.8	101.7	99.0
T_02	Hindu Kush crossing	310.1	238.2		19.8	52.1
T_03	NEPS to SEPS interconnector	238.2	191.3		47.0	
T_04	Connection to Pakistan	112.8		83.1		29.7
T_05	Herat interconnector	176.1	48.6	52.8	38.4	36.3
	Reactive power compensation	46.5	10.4	5.2	6.0	24.9
	Total	1726.8	595.0	676.9	212.9	242.0
T_06	CASA-1000	873.0	228.0	645.0		

Table 12.1-3: Stages and investment for major transmission projects

The detailed breakdown of the investments required for generation expansion according to the optimized scenario and implementation of the major transmission projects over the years is given in **Annex 12.1-2**.

There are some dependencies between the projects to be considered. For example the construction of the NEPS to SEPS interconnector is a precondition for the connection of the provinces along the line route and implementation of stage A of the additional Hindu Kush crossing will be necessary to wheel the additional power available with stage B of the new Turkmenistan to Afghanistan interconnector.

Furthermore, the relation between the major transmission projects of the NEPS to SEPS interconnector and the Herat interconnector and the measures for electrification within the provinces has to be considered within the overall project implementation procedure.

The total investment required for the development according the optimized scenario is given in the following table:

Overview on Investment type	Investment optimized scenario [m$]				
	Subtotal by project	Stage A	Stage B	Stage C	Stage D
Generation development	7329.6	327.6	348.5	981.5	5671.9
Major transmission projects	1726.8	595.0	676.9	212.9	242.0
Transmission development within the provinces	1040.1	290.1	439.8	215.1	95.0
Total	10096.4	1212.7	1465.2	1409.5	6009.0

Table 12.1-4: Stages and total investment for the development of the power system, optimized scenario

To consider the whish, expressed by the Ministry during the workshop held in February 2013, of considering optimistic assumption for commissioning of power plants from local resources an optimistic scenario was developed. For this scenario commissioning of a coal fired power plant along the Bamyan route was considered for 2020. Furthermore the assumption was taken that earliest commissioning date for Kajaki Addition HPP and Surobi 2 HPP could be 2017 and 2018.
Based on this optimistic assumption the optimization process leads to an more expensive expansion of power generation and to higher costs for the power supply in Afghanistan. The resulting generation development for the optimistic scenario is given in the table below.

Generation expansion project		Investment power plant plus networkintegration[m$]				
		Subtotal by project	Stage A	Stage B	Stage C	Stage D
G_01	Salma HPP	236.6	236.6			
G_02	Kajaki Expansion HPP	91.1	91.1			
G_21	Sheberghan TPP 2x200MW	697.0		697.0		
G_10	Kunar B HPP	633.0				633.0
G_05	Kunar A HPP	2086.8				2086.8
G_22	Ishpushta TPP 400MW	761.1		761.1		
G_06	Kajaki Addition HPP	314.8		314.8		
G_23	Dara-i-Suf TPP 800MW	1484.2				1484.2
G_12	Olambagh HPP	410.3				410.3
G_09	Kama HPP**	190.0				190.0
G_04	Sarobi 2 HPP*	713.2		713.2		
	Total	7618.1	327.6	2486.2	0.0	4804.3

Table12.1-5: Stages and investment for power generation expansion optimistic scenario

The detailed breakdown of the investments required for generation expansion according to the optimistic over the years is given in **Annex 12.1-3**.

The total investment required for the development according the optimistic scenario is given in the Table 12.1-6:

Overview on Investment type	Investment optimistic scenario [m$]				
	Subtotal by project	Stage A	Stage B	Stage C	Stage D
Generation development	7618.1	327.6	2486.2		4804.3
Major transmission projects	1726.8	595.0	676.9	212.9	242.0
Transmission development within the provinces	1040.1	290.1	439.8	215.1	95.0
Total	10384.9	1212.7	3602.9	428.0	5141.3

Table 12.1-6: Stages and total investment for the development of the power system, optimized scenario

12.2 Update of the Master Plan and Capacity Building

In general, an update of Power Sector Master Plan has to be carried out on regular basis every three to five years. For Afghanistan situation, on development of infrastructure and economy are high. Input data for demand forecast and the power sector master plan are subject to continuous change and an update will be required to take into account the future development.

Therefore it is recommended to establish a continuing procedure for repeatedly collection and revision of the basic data.

- Update of demand forecast by considering the main parameters
- Following up of the feasibility of power generation options
- Following up ongoing projects in power generation and transmission
- Considering development and requirements in the power distribution

Updating of the master plan requires establishing of a planning group of defined structure and responsibility with permanent and temporary members. The people must be integrated into the Ministry of Energy and Water and DABS with interdisciplinary functions.

Permanent members are responsible for regularly update of the master plan and the temporary members are involved for discussion and collection of input data.
The working areas of involved persons should cover the different disciplines and responsibilities as:

- technical planning and operation
- power plants and transmission network
- commercial departments and accounting
- Other planning departments

For the challenging task of building an integrated network within Afghanistan and to provide power for entire population it is required to take substantial measures for capacity building of the responsible staff within MEW and DABS.
There are on the one hand the issues to be covered for Master Plan update as:

- Methodology used for Planning
- Preparing demand forecast
- Optimized generation expansion
- Network expansion planning
- Cost estimation
- Economic and financial aspects
- Project management and reporting
- Usage of planning software

On the other hand the general tasks need to be processed in DAB and the MEW will requires capacity building to cope with the increasing challenge for operating a integrated power system in Afghanistan from the technical as well as the financial, legal and economical point of view.