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Afghanistan Renewable Energy Development Issues and Options

Issues and Options

EXECUTIVE SUMMARY

Afghanistan is facing many economic and political challenges as it deals with spreading insurgency, declining economic growth, and continuing poverty. The Government is working on a number of fronts to stimulate economic activity through its own initiatives and in partnership with International Development Organizations but will continue to be challenged in the near and medium term as a growing population seeks jobs and business opportunities.

One of the initiatives that the Government of Afghanistan (GoA) has identified is to capitalize on its wealth of Renewable Energy (RE) resources with a view to both increasing the delivery of electricity services to the population and developing domestic business opportunities both directly linked to RE technology and linked to improved access to reasonably priced electricity. Specifically, the GoA has set a target to supply 10 percent of forecast electricity demand (350-500 MW) through RE by 2032.

This initiative offers both opportunities and risks. The objective of the current paper is to review the potential viability of RE as part of the country's electricity supply plan, and at the same time to identify issues that might hinder or even derail the process.

Existing Electricity System

The existing power supply system in Afghanistan is deficient in many respects including geographic coverage, flexibility and adequacy and cost of domestic supply. While 89 percent of households reported having some kind of access to electricity in the 2013-2014 Living Conditions Survey (ALCS)[1], only 29.7 percent received their power from the grid. Grid supply largely consists of imports from neighboring countries, supplemented by electricity from domestic hydropower plants (HPPs). Most of the HPPs have minimal reservoirs and are unable to provide storage beyond a few hours. Peak flow for hydro is normally in the summer months, in contrast to peak customer demand which is in the winter. Domestic thermal plants make a small contribution to the total supply, but are fueled by imported diesel and are extremely costly to operate.

The transmission system is fragmented, consisting of isolated grids or islands supplied by different power systems including different generating stations and different import sources. The power systems of the countries serving Afghanistan's import needs are not synchronized with one another (although the Turkmen system is synchronized with that of Iran), forcing Afghanistan to operate sections of its network at differing speeds and frequencies in order to interconnect with the neighboring systems. While imports have helped Afghanistan grow its electricity

[1] Central Statistics Organization (2016), *Afghanistan Living Conditions Survey 2013-14. National Risk and Vulnerability Assessment*. Kabul, CSO

consumption, asynchronous supplies limit the opportunities to interconnect to improve security of supplies and expand the power network in a rational way.

Supply Demand Gap

There is a growing gap between demand and supply, but existing forecasts of demand do not reflect the current reality in terms of both stalled economic growth and growing security concerns. Between 2010 and 2015, the number of household connections to the grid increased by 60 percent and total connections by 57 percent. Households dominate the customer base, representing almost 93 percent of total connections, while commercial customers represent just under 7 percent and government agencies less than 1 percent.

The most recent and comprehensive forecast of electricity demand in Afghanistan was developed as part of the preparation of the Afghanistan Power Sector Master Plan (APSMP).[2] Net demand was projected to increase from approximately 2,800 GWh in 2012 to 15,909 GWh in 2032, representing an average annual growth rate of 9.8 percent. Peak demand was forecast to increase from approximately 600 MW at the beginning of the forecast period (2012) to a projected 3,502 MW in 2032 - approximately 8.6 percent per year. It is this demand projection that the GoA is proposing to meet at least in part with RE. However, the assumptions underlying these forecasts, particularly in terms of economic growth, have failed to materialize and the projections are not a satisfactory basis for planning on a system-wide scale. In the near term, disaggregated forecasts for more focused potential markets would be more useful.

Rich Renewable Resources

Afghanistan enjoys an abundance of RE resources, whose exploitation could help to alleviate future supply gaps at cost levels that are both economically and financially attractive. Total hydroelectric capacity (recoverable) is estimated at 23,000 MW, of which 87 percent (20,000 MW) is in the north-east on the Amu Darya, Panj and Kokcha Rivers. A further 8 percent (1,900 MW) is located to the east of Kabul, with over half of this on the Kunar River near the border with Pakistan. Feasibility studies for the exploitation of these resources are incomplete and out of date, but notionally indicate Levelized Costs of Energy (LCOEs) in the order of US$0.045 to over US$0.10 per kWh. However, if storage or backup capacity were included (flows are highly seasonal and peak in the summer while demand peaks in the winter), the true costs would be considerably higher.

With 300 days of sunshine each year, average solar potential (Global Horizontal Irradiance or GHI) is estimated at 6.5 kWh per m^2 per day. Higher values prevail in the southern areas of Kandahar, Helmand, Farah and Herat provinces, but even in the northern provinces, where irradiance averages only 4.5 kwh per m^2 per day, electricity generation is technically feasible.[3]

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[2] Fichtner, Islamic Republic of Afghanistan, Power Sector Master Plan, Final Report, April 2013

[3] Nagsaka/ Anwarzai (2017), “Utility-scale implementable potential of wind and solar energies for

Total estimated national capacity based on solar radiation and feasible area is 222,000 MW. Globally, LCOEs for solar average in the order of US$0.10/kWh, excluding storage, but solar costs are expected to continue to decline and several planned projects are purported to be much more attractive financially.

Afghanistan's wind resources are also substantial, but highly localized with the areas of maximum potential located in the southwest near the Iranian border. In all, the country's total capacity is estimated at approximately 150,000 MW, while exploitable capacity (i.e. that not constrained by accessibility or terrain) is estimated to be roughly 66,700 MW. Looking at international experience, the average LCOE for land-based wind energy is in the order of US$0.065/kWh in OECD countries and slightly higher elsewhere. There are indications that geothermal and biomass may also have substantial potential, but additional study of these resources is needed.

Integrating RE into the Supply Plan and Viability Assessment

Identifying and evaluating opportunities to integrate RE into the overall electricity supply plan presents some unique challenges. Generally traditional planning models which attempt to optimize, in terms of size and timing, among a range of generation options are not well suited to evaluating resources whose cost effectiveness can vary widely depending on location and market density. Some attempts have been carried out in Afghanistan to determine the most appropriate roles for renewables, including hydroelectricity, utility scale solar and wind, and off-grid solar and wind options. While the value of some of this work is limited by the poor quality of the input data, the exercise has been helpful in identifying some of the challenges of planning for renewables, and the outcomes provide some useful insights.

The APSMP utilized optimization models to create an electricity supply plan to meet projected demand growth. The models included an assessment of the potential role of large hydropower plants (HPP) in the optimal generation mix, but did not address possible grid-based roles for other RE resources. In theory, the APSMP could provide a framework for incorporating other grid-based RE into the Plan by substituting RE options for other proposed new plants where the costs of RE are projected to be competitive. This might include replacing some of the gas-fired thermal plants, high cost HPPs or even some imports with utility-scale solar or wind farms. Care would need to be exercised, however, as conditions have changed significantly in the 4 years since the Plan was prepared. Stagnant economic growth would suggest that demand forecasts are unduly optimistic, while delays in the implementation of ongoing projects suggests that the timing of new capacity needs to be reviewed.

Afghanistan using GIS multi-criteria decision analysis", *Renewable and Sustainable Energy Reviews*, Vol.71, May 2017.

Another recent study combined GIS and resource data to define areas of the country where grid-scale solar and/or wind farms were physically and economically viable.[4] The study determined that large areas of the south and south-west showed potential to supply upwards of 20,000 MWh per year of solar electricity per spatial unit (2 km x 2 km areas). Overall, the supply capability of those areas that met the inclusion criteria for solar installations averaged 20,559 MWh per year at average costs that ranged from a low of US$0.097 per kWh to a high of US$0.137 per kWh (excluding interconnection to the road and transmission system which would add in the order of 20 percent to these costs). The analysis of wind potential identified areas in the south, southwest and northwest with potential to supply wind energy, although the areas of highest productivity were concentrated in the western parts of Herat and Farah provinces with potential outputs of 30,000 – 50,000 MWh per year per spatial unit. The overall annual output capacity of the areas identified as having potential to accommodate wind developments averaged 21,285 MWh per spatial unit per year. Expected LCOE's for the generation component of wind supply in project-capable spatial units were as low as US$0.05 per kWh, although costs in some of the areas that had technical potential averaged as high as US$0.197 per kWh. As technology and competition continue to place downward pressure on installed costs, future LCOEs are expected to decline even further with generation costs at potential solar sites ranging from US$0.071 to US$0.102 per kWh.

A third study combined GIS based analysis with an optimization model to determine the optimal size of solar and wind installations in different parts of the country - either stand-alone, mini-grid or utility scale. The study found that at low consumption levels, grid connection was the best option only for settlements close to previously connected villages and transmission lines. Stand-alone systems such as SHS were preferred for more remote settlements. As consumption per household increased to mid-range levels, connection to the grid became attractive to households at increasing distances from the existing transmission lines. High consumption levels further expanded the range at which grid connection was the best option. However, at these consumption levels, mini-grids became more attractive than stand-alone systems for households further removed from the grid. Overall, the model found that off-grid systems were most attractive for between 55 and 73 percent of the population.

The GoA and World Bank are currently working together to expand the GIS analysis to identify potential sites for utility scale solar in selected areas of interest. GIS-based studies of the future potential for RE development show strong promise to yield useful findings regarding the optimal role of RE in the future generation expansion program. In many instances, however, the available input data is limited or out-of-date and as such the results of the work are suspect. As a follow-up of this study, the Bank is supporting the GoA on site identification and feasibility

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[4] Since the study assumed that the solar or wind facility would be connected to the grid, the costs of backup storage were not included in the costing exercise as the grid would provide backup supply when the RE resource was unavailable.

analyses of grid wind, solar PV and CSP at the project level. Moving forward, key initiatives to improve the quality of planning for RE would include:

- Developing realistic and up-to-date estimates of the costs of constructing RE supply sources, both in different locations and at different scales. This includes the cost of constructing the large HPPs that form a part of the APSMP, and the costs of storage or backup supply to offset the variability of RE resources.
- Updating the costs of alternative supply sources including gas and oil-fired diesel, other thermal plants and imports.
- Updating the demand forecast both for households and for commercial and industrial enterprises. The household energy survey ongoing in early 2018 under the Afghanistan Energy Study will provide useful input to the projection of household demands and to the better understanding of how electricity fits into the household energy mix.

Risks and Barriers

While much is in place in support of the successful establishment of RE in the country, there are some key issues that could represent risks or barriers to full development of the sector. Five major categories are discussed in this paper, including:

- Security and political risks
- Technical barriers
- Commercial risks
- Financing barriers
- Gaps in the legal and regulatory framework

Security and political risks are self-explanatory. Technical barriers relate primarily to the limitations of the grid both in terms of geographic coverage and operational synchronization. Commercial risks relate to uncertainties about the commitment and credit-worthiness of the off-taker (most likely DABS), currency exchange risks as costs and revenues may be in different currencies, and risks related to lack of clarity of land rights and ownership.

Financing barriers include the lack of commercial financial institutions either located or operating within the country. The difficulty of accessing credit through banks and other formal financial institutions leaves most existing firms dependent on the informal financial sector (family funds, retained earnings etc.). There is also a lack of private insurance or guarantees against commercial risks. Finally, there is only limited availability of flexible micro-credit programs of the sort that might finance small-scale, community or household level investment in RE.

Gaps in the legal and regulatory framework also represent risks to potential RE developers. For example, under current conditions, a potential RE developer has to negotiate an off-take obligation with DABS in specific tailormade agreements (PPAs) for each project. There is also a lack of clarity over the permitting process, as Islamic, statutory and customary rules can conflict and there is uncertainty about which will prevail in a particular situation. In addition, there is no clear legal and regulatory framework that applies to stand-alone and mini-grid projects as opposed to a utility-scale initiative. This hinders the ability to develop small projects even though their scale may be most economical.

Planning and management of RE development is spread across a number of agencies, all of which are in need of institutional strengthening., and lack of coordination among them can lead to long lead times for projects. This ad-hoc approach also spills into lack of donor coordination, which has resulted in concurrent, sometimes overlapping work being done with supporting development partners. Shortcomings in the institutional framework also impact potential investors since there is no clear one-stop shop for RE development. There are also many accompanying regulations and laws will need to be passed to ensure its effective implementation. Issues such as the nature and structure of the regulatory authority, tariff setting mechanisms, and the rights and obligations of the GoA and DABS with respect to private sector developers all need to be defined and codified.

Improve Enabling Environment

Testing risk mitigation measures through piloting projects. While the ideal way to address these risks and barriers would be to correct the underlying problems, this process is likely to take considerable time. In the interim, there are some actions that could be taken to advance the development of RE projects within the limitations of existing shortcomings. One way to do this would be to improve the utilization of available financing and risk mitigation instruments. These include concessionary funds available through the various International Financing Institutions (IFI's), as well as guarantees available at the macro and project level.

A related option would be to create a safer environment for investors through the use of contracts between the GoA and its agencies and potential project developers. So-called 'regulation by contract' replaces the need for a comprehensive legal and regulatory framework with project-specific terms and conditions which define the rights and obligations of the major stakeholders. The 50 MW Mazar IPP provides an example of a contractual framework that substitutes for the absence of legal and regulatory clarity, and defines offtake and payment obligations for DABS, gas supply obligations of the national gas company, land use and ownership rights and penalties for non-compliance. A sovereign guarantee commits the Ministry of Finance to ensure that payment obligations are honoured and is to be back-stopped by a guarantee provided by the World Bank through IDA. The Mazar arrangements could provide a model for initial investments in RE.

Other near-term initiatives include the establishment of a 'one-stop-shop' and the utilization of 'pay as you go' models. A standardized one-stop-shop (OSS) scheme which combines financing, risk mitigation facilities, and institutional support could enable a speedy delivery of competitive tariffs, reputable developers and contractors, high quality installations and certainty of delivery by a set date. In parallel, it can provide investors/developers with certainty of process, low transaction costs, a robust and bankable contractual package and a de-risking of their investments in the respective markets. Pay as you go (PAYG) is a revenue model that lets buyers pay small amounts for utilities 'on-demand'. The systems are sold against a small upfront payment and regular 'top-ups', ideally sent via low-cost mobile money services. The Lighting Afghanistan program seeks to support development of PAYG models by providing market intelligence and quality assurances for manufacturers and suppliers of equipment. While PAYG has not yet been implemented in the country, a prepaid metering model for collecting revenue has been implemented for the Bamyan Renewable Energy Program (BREP).

Climate Resilience and Long-term Energy Security

One risk which is beyond the control of implementing agencies is the effect of climate change and natural hazards. Vulnerability to these is particularly relevant given the uncertainties regarding the long-term effects of climate change as well as the significant natural hazards prevalent in Afghanistan. Average annual temperature is projected to increase between 1.4 °C and 4.0 °C by the 2060s, and between 2.0°C and 6.2 °C by the 2090s. Precipitation, which is already low, is unlikely to change significantly, but extreme hot days will increase, and glaciers will continue to retreat. Loss of glacier mass and snow cover are projected to accelerate throughout the twenty-first century, reducing water supplies and hydropower potential.

Availability of water resources against climate uncertainties for future hydropower generation raises one of the major concerns for the country's long-term energy resilience and security. With climate projections emphasizing the vulnerability of water resources, identification of sites for new HPP is a critical area. Future potential HPP sites may not be suitable for hydropower, and current HPP may be losing productivity, partly because of increased use of water for irrigation upstream. Most micro HPP are of the run-of-river type and do not include a water reservoir, making them more vulnerable to variation of river flow.

Introducing other power generation resources such as solar and wind into the sector planning can potentially help improve the resilience of the system. Research on climate change impacts on wind energy conducted in specific geographic regions consistently indicate a small or negligible effect of climate change on wind energy output. The impact of climate change on solar PV and CSP output is generally small, and on a planetary scale depends on the source location. Simulation studies indicate that PV increases or decreases by a few percent, depending on geographic location. CSP is more sensitive to climate change with larger percent changes (e.g., more than 10% in Europe), but still very location dependent.

The electric grid is a major source of vulnerability in the energy system. An assessment of risks from major natural hazards and disasters in Afghanistan was conducted in this study, including fluvial flood, flash flood, drought, landslides, avalanches and earthquakes. The analysis estimates the probability of occurrence of each hazard throughout the entire territory and produced risk maps. The risk information determined by the analysis was then used to assess the vulnerability of the energy system to natural disasters. A possible adaptation measure for the energy system is represented by transitioning toward more resilient power generation and transmission models, such as a decentralized power system, and the integration of distributed generation from renewable sources with intelligent grid systems. The limited reach of regional grids in Afghanistan implies that smaller scale off-grid renewable energy technologies such as small hydro, wind solar PV and solar CSP can be major factors in a development program by providing access to energy, particularly in rural areas.

Conclusions and Recommendations

The review undertaken in this study aimed to identify the issues and options surrounding development of RE resources to improve access to cost effective and reliable electricity supply in Afghanistan. Key findings included the following:

- There are growing gaps between the demand for electricity and the supply from the grid, especially outside urban areas. Existing thermal capacity is extremely costly to operate and continued and growing reliance on disparate import sources prolongs the problems associated with lack of grid integration
- RE resources are abundant, particularly wind and solar, and their potential far exceeds the GoAs modest goals for their contribution to energy supply. The costs of exploiting either of these resources have fallen significantly in recent years and compete favorably with the costs of conventional thermal and many hydro projects.
- Options exist for both utility scale and small scale (mini-grid or stand-alone) installations. Utility scale is viable where there is significant demand which can be accessed without significant investment in grid expansion, and where other generation is available to offset the variability in RE supply.
- Mini-grid and stand-alone solutions are preferred in areas where the cost of grid connection is substantial; costs generally compare favorably with conventional small-scale thermal which is typically fueled by imported diesel. A number of community level projects have already been undertaken under the NSP to install mini-grids in rural areas based on micro- and pico-hydro and small scale solar installations. These projects represent a model for further initiatives to extend electricity supply to areas where grid access is unlikely to be viable in the foreseeable future.
- Good modelling tools are available which are (and will continue) being used to identify appropriate sites for development. The tools would benefit, however, from better data on the country-specific costs of supply, both for RE and for alternative generation resources, as well as from updated demand forecasts. Ongoing and future Technical Assistance (TA) studies could usefully focus on these areas.

- While steps have been taken to develop a supportive legal and regulatory framework for RE development in the country, including policy statements, legislation and institutional reform, challenges remain. The institutional framework is cumbersome and lacks capacity, and responsibility for RE development is divided both within and between ministries. In addition, procedures for sector regulation, tariff setting, and interaction with the private sector are not yet fully defined. Reform in these areas needs to be accelerated, especially to clarify and streamline responsibility for the development of RE resources.
- There are a number of other barriers to RE development which will take time to resolve. These include security risks, shortage of financial resources, the tenuous commercial viability of DABS, which would either be the primary financer or primary offtaker for new generation resources, and ongoing technical challenges related to grid integration and the limited options for storage to compensate for supply variability. Security risks make location selection particularly important. Technical challenges also limit the number of viable locations both for utility scale and community level projects.

Priority Next Steps:

- In the near term, financing and commercial risks to utility scale projects can be addressed by choosing one or more pilot projects of modest scale, located in a secure sector with a confirmed market. Working with the GoA, identify potential target sites for priority development and confirm potential market, optimal capacity and detailed cost estimates. Sites adjacent to existing HPPs might be attractive candidates as they offer an existing security infrastructure, an established link to markets, and a possible offset to the variability of the RE resource.
- Encourage private sector involvement in financing and operations using contracts and guarantees to compensate for limitations in the legal framework and the need for financial security. The WB can support these efforts by promoting awareness of IDA and MIGA guarantees.
- Prioritize institutional reforms that facilitate implementation of RE projects. These include rationalization of the institutional framework for the sector as well as the establishment of a one-stop shop for project licensing and approvals.
- Improve and expand the database for RE planning in the country. In particular, additional information is needed with respect to potential electricity demand, and country-specific costs of supply.
- While the focus of the paper has been on grid-scale development, RE is also a viable option for off-grid installations, and already plays a significant role in supplying households and enterprises with electricity through solar and hydro based mini-grids and solar home systems. Community level initiatives should be encouraged, as they represent a mechanism to both build markets for future grid interconnection as well as a support to local economic and social development.

Contents

Afghanistan Renewable Energy Development
Issues and Options

1 INTRODUCTION

1.1 Country Context

Afghanistan faces a fragile future on many fronts. Hindered by conflict and corruption, the leadership has struggled to find a route to sustained economic growth. Foreign aid, together with the presence and spending of international military personnel provided an economic stimulus between 2001 and 2012, but the subsequent withdrawal of foreign troops also signalled a sharp decline in the GDP growth. Since 2012, economic growth has slowed dramatically from percentage rates in the teens to 2.7 percent in 2014 and an estimated 1.3 percent in 2015. 2016 saw a slight recovery to 2.4 percent, and 2017 is estimated to have seen 2.5 percent growth but still well below the double-digit growth rates during the occupation.

Currently Afghanistan is ranked as one of the least developed countries in the world. The 2016 UN Human Development Index ranked it at 169 out of 188 countries[5], with poor performance in life expectancy, education, gender equality and percent of the population living in or close to multidimensional poverty. Based on the 2013-2014 Afghanistan Living Conditions Survey[6] (ALCS), over 39 percent of the population lived in poverty – up from 36 percent in 2012, and unemployment stood at 22.6 percent of the labor force. There are also disparities in the incidence of poverty with poverty rates in rural areas approximately 10 percentage points higher than in urban centers. A significant gender imbalance remains as reflected in the average literacy rate (population above 14 years of age). While the Afghan average literacy rate is 35 percent countrywide, only 20 percent of female Afghans are literate.

Slow growth, an unstable political situation, and ongoing insurgency create a challenging environment going forward. The country is already suffering from under-utilization of resources - both labor and capital. The problem is compounded by the rapid population growth and the large number of young people who will be entering the labor force in the coming years as over 44 percent of the current population is under the age of 15. New sources of economic growth, including new employment opportunities, are needed to absorb the existing surplus of inputs, as well as new entrants to the labor pool.

[5] United Nations Development Programme (UNDP), *Human Development Report 2016, Human Development for Everyone, Statistical Annex*

[6] Central Statistics Organization (2016), *Afghanistan Living Conditions Survey 2013-14. National Risk and Vulnerability Assessment (NRVA)*. Kabul, CSO

Electricity supply represents both a problem and a possible path towards improving living conditions and economic opportunities. Analysis of the ALCS data indicated that at the time of the survey, the electricity grid extended to only 30 percent of the population, and there has been little to change that situation in the intervening period. Moreover, grid supply has often been insufficient to meet even known demands, let alone those that would prevail if supply were available. A reliable and cost-effective supply of electricity is generally believed to be a necessary precursor – or at least a contributing factor - to economic development, both as it offers increased business and employment opportunities and as it contributes to the standard of living. As a result, both the government and the donor community are prepared to invest in measures that would increase the share of the population with access to electricity.

A number of initiatives are moving forward, including investment in transmission lines that would increase the country's capacity to import low-cost electricity from neighboring countries and solicitation of private-public partnerships to develop new gas-based supply sources. The Government of Afghanistan (GoA) has also made a commitment in this regard to pursue opportunities to exploit the country's ample resources of renewable energy (RE). While the focus of the initiative entails involving the private sector, the concept in itself is valid even for national investment provided the electricity can be generated and delivered in a cost-effective manner.

1.2 Objective and Organization

This initiative offers both opportunities and risks. The objective of the current paper is to review the potential viability of RE as part of the country's electricity supply plan, and at the same time to identify and review issues that might hinder or even derail the process. The report is divided into 7 chapters. Chapter 2 looks at the current and projected supply-demand balances in the country to assess what is needed in terms of future supply of capacity and energy. Chapter 3 provides an overview of the nation's potential to supply electricity based on RE resources, together with an assessment of the costs of supply. Chapter 4 reviews ways in which planning tools can be used to identify and rank viable options for RE supply and discusses the findings of some recent planning initiatives.

Chapter 5 looks at the current legislative and regulatory framework for RE development, and assesses how the existing Afghan framework satisfies international best practices as well as areas in which it falls short. Chapter 6 provides an assessment of the administrative barriers and systemic risks faced by potential investors in electricity sector development, and offers an action plan to address these as well as to make the sector more attractive to private sector development. Finally, Chapter 7 takes a look into the future and discusses ways in which climate change and risk of natural disasters might affect the future of RE development and ways in which these risks might be mitigated.

2 SUPPLY-DEMAND BALANCES

2.1 Current Electricity Supply

Power supply in Afghanistan is delivered through a combination of grid-based systems, mini-grids and stand-alone facilities. While 89 percent of households reported having access to electricity in the 2013-2014 Afghanistan Living Conditions Survey (ALCS)[7], only 29.7 percent received their power from the grid. Rural and urban areas differed markedly in this regard, however. Table 2.1 below shows the breakdown between rural and urban households in terms of electricity access and the primary source of electricity supply. As the table shows, grid supply dominates for urban households, but represents the primary supply source for only a small portion of electrified rural households.

Table 2.1 Electricity supply by type of generation

% of Households	National	Rural	Urban
Access to electricity			
Yes	89.0	85.9	98.6
No	11.0	14.1	1.4
Source of Electricity			
Grid	**29.7**	**10.9**	**88.8**
Government Generator	0.7	0.2	2.2
Private Generator - Engine	0.8	0.7	1.0
Private Generator - Hydro	1.2	1.5	0.1
Community Generator - Engine	0.4	0.5	0.3
Community Generator - Hydro	7.4	9.7	0.1
Solar	46.4	57.9	10.2
Wind	0.4	0.6	0.1
Battery	11.6	14.3	3.3

Source: ALCS 2013-2014

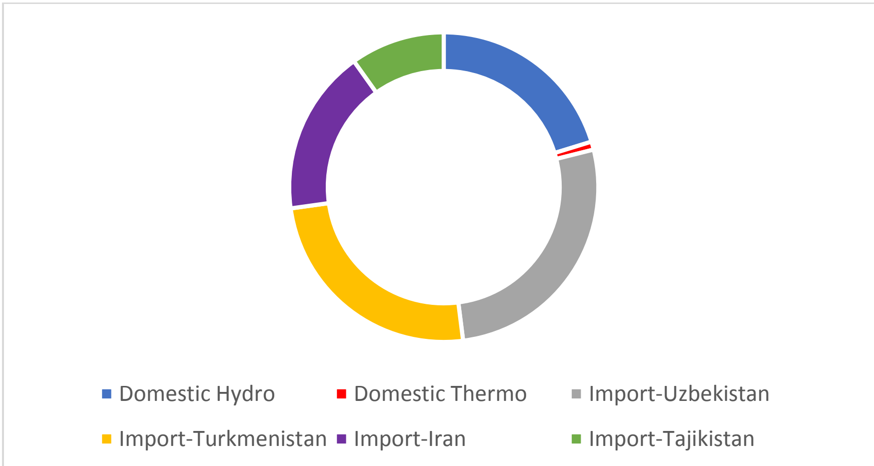
***Grid Based Electricity*:** The grid-based power network is operated by Da Afghanistan Breshna Sherkat (DABS), a vertically integrated government owned entity which was spun off from the Ministry of Energy and Water (MEW) in 2009. Initially, DABS was only responsible for the daily operation of the transmission and distribution system (T&D), but it is increasingly involved in investments in new T&D capacity.

Electricity supplied to the grid consists primarily of imports from neighboring countries, as displayed in Figure 2.1 below. A total of 3,767 GWh were imported in 2015-2016 - an estimated 80 percent of total grid supply. Uzbekistan was the main source (1,284 GWh), followed closely

[7] Central Statistics Organization (2016), *Afghanistan Living Conditions Survey 2013-14. National Risk and Vulnerability Assessment*. Kabul, CSO

by Turkmenistan (1,184 GWh). Iran supplied 827 GWh and Tajikistan supplied 471 GWh. Domestic generation totaled 1,007 GWh, and was almost exclusively (96 percent) hydro.

Figure 2.1 Grid Electricity Supply of Afghanistan, 2015-16



In mid-2015 there were 12 hydropower plants (HPPs) in Afghanistan, with a total installed capacity of 254 MW.[8] (See Table 2.2 below) The two largest are Naghlu Hydropower Plant at 100 MW installed capacity and Mahipar Hydropower Plant at 66 MW installed capacity. While some of the plants are operating below their rated capacities, a comprehensive program of rehabilitation is ongoing and many of the plants have already been upgraded. Typically the HPPs have minimal storage, and can only manage output over the course of a few hours.

Table 2.2 Existing Hydropower Plants

Name	River	Capacity after rehabilitation [MW]	Date of commissioning / rehabilitation
Naghlu	Kabul	100	1967 / mid 2013
Sarobi	Kabul	22	1957 / completed
Mahipar	Kabul	66	1967 / completed
Darunta	Kabul	11.5	1964 / 2012
Assassab.	Kunar	0.7	1983 / *
Charikar	Ghorband	2.4	1973 / *
Jabul Ser.	Salang	2.5	1920 / *
Ghorband	Ghorband	0.3	1975 / *
Kajaki (I & III)	Helmand	33	1975 / completed
Grishk	Helmand	2.4	1957 / *
Pul-i-Chomri	Pulikhumri	3x1.37=4.12	1950 / 2013-2015
Pul-i-Chomri II	Pulikhumri	3x2.93=8.79	1962 / 2013-2015

[8] Website of the Afghanistan Interministerial Commission for Energy, https://sites.google.com/site/iceafghanistan/electricity-supply/domestic-generation-1/domestic-hydro-generation

Thermal capacity totaled 312 MW, of which the largest were Tarakhil (105 MW), Kandahar (63.5 MW), Khairkhana AEG (50 MW) and Khairkana BBC (45 MW). Most of the remaining plants are small - less than 5 MW.[9] The thermal plants are fueled by imported diesel, which makes them extremely costly to operate, and as a result they made little contribution to the power generation mix which favored low cost imports and the use of domestic hydropower.[10]

Transmission Network: The Afghan transmission system is highly fragmented, consisting of isolated grids or islands supplied by different power systems including different generating stations and different import sources. The power systems of the countries meeting Afghanistan's import needs unfortunately operate asynchronously with one another and with Afghanistan (although the Turkmen system is synchronized with that of Iran). Importing power from these different countries means that Afghanistan has to operate several separate power systems each synchronized with its neighboring supplier or with its own domestic supply (which is itself not synchronized). While this has helped Afghanistan grow its electricity consumption over the last five years, asynchronous supplies limit the opportunities to interconnect to improve security of supplies and expand the power network in a rational way.[11]

For operational purposes, the network is divided into four major working groups linking different supply sources to the grid: i) the North East Power System (NEPS), which consists of multiple small islands and connects 17 load centers including Kabul, Mazar-e-Sherif, and Jalalabad with Tajikistan and Uzbekistan (at 220 kV, 110 kV, and 35 kV); ii) the South East Power System consisting of Khandar and linking with Kajaki (110 kV); iii) the Herat System linking with the Islamic Republic of Iran and the Republic of Turkmenistan (132 kV and 110 kV); and iv) the Turkmenistan System linking Herat Faryab, JawzJan, Sar-e-Pul, and Andkhoy Districts (110 kV). Note that because the NEPS receives power from both Uzbekistan and Tajikistan, as well as a number of domestic generating stations, parts of the system operate in asynchronous mode.

Off-Grid System: According to the ALCS, most off-grid households rely on solar power - presumably solar home systems (SHS). However, there has also been an aggressive program of developing off-grid micro-hydro with an estimated 5,000 projects implemented under the National Solidarity Program (NSP). To date, solar potential has not been exploited for large scale projects except for the 1 MW plant at Bamyan. However, numerous small-scale installations have been built under the NSP and bilateral donor funded projects. Of the more than 8,300 power projects that have been implemented under the National Solidarity Programme (NSP)[12], a significant

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9 Website of the Afghanistan Interministerial Commission for Energy, https://sites.google.com/site/iceafghanistan/electricity-supply/domestic-generation-1/domestic-thermal-generation

10 While diesel prices vary with international petroleum prices, at current (April 2018) prices (US$ .585/l) the cost of diesel generation would range from US$0.21/kWh at a 60% plant factor to US$0.32/kWh at a 10% plant factor. Counting only fuel and variable O&M, generation cost would be approximately US$0.19/kWh

11 ESMAP, *Energy Security Trade-Offs under High Uncertainty: Resolving Afghanistan's Power Sector Development Dilemma*, March 22, 2016

12 Ministry of Rehabilitation and Rural Development, NSP Quarterly Report, September 23 to December 21, 2015

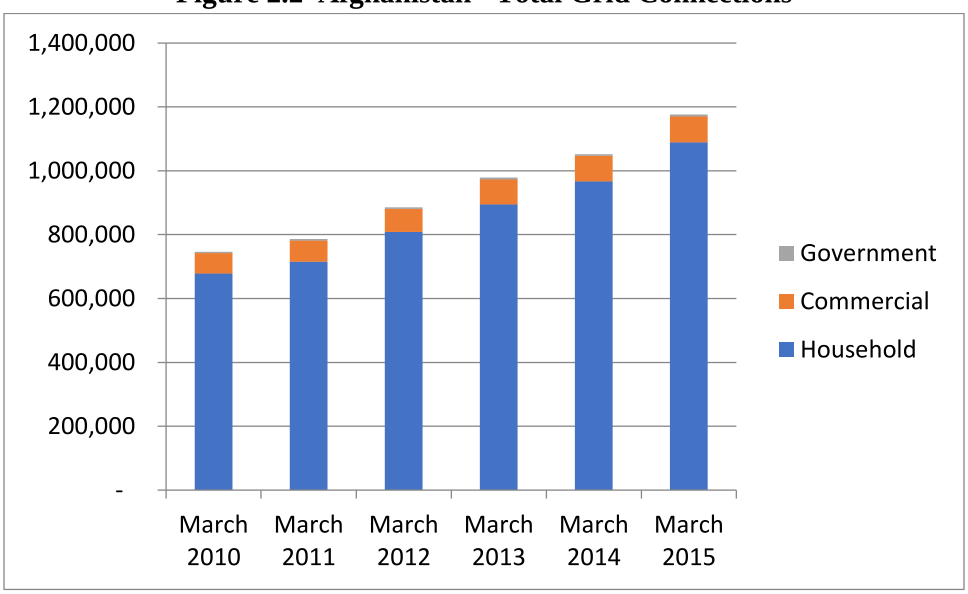
proportion have been based on renewables. The Rural Energy Department of the Ministry of Energy and Water (MEW) has also developed a searchable database covering a total of 5,194 RE projects implemented under several programs, including NSP. Of these, 2,450 projects were based on solar, mainly the acquisition of solar panels to supply a mini-grid, but also including solar hot water systems, pumps, and individual systems for clinics, schools, and mosques.[13]

2.2 Current Electricity Consumption

Electricity demand has been growing steadily and rapidly. As noted in Table 2.1, 86 percent of rural households and almost 99 percent of urban households had access to some form of electricity supply as of 2014 and grid based supply in urban areas reached almost 89 percent of households. Total supply from the grid in 2015-16 was 4,773 GWh, of which 3,767 were imports. Hydro constituted 967 GWh, and thermal made up the remaining 39 GWh. Sadly supply has not kept up with the growing demand and the system suffers from frequent service interruptions. The supply situation is aggravated by the reliance on imports whose transmission linkages are vulnerable to acts of sabotage.[14]

Figure 2 below shows the pattern of growth in connections between 2010 and 2015. Over that period, the number of household connections increased by 60 percent and total connections by 57 percent. Households dominate the customer base, representing almost 93 percent of total connections, while commercial customers represent just under 7 percent and government agencies less than 1 percent.

Figure 2.2 Afghanistan - Total Grid Connections



[13] Website, Afghanistan Ministry of Energy and Water, http://red-mew.gov.af/red/login/reports
[14] Taliban Sabotage Cuts Major Power Source for Afghanistan Capital, New York Times, January 27, 2016

Source: DABS

The primary household use of electricity is for lighting. In the 2013-2014 ALCS, 80.3 percent of rural households and 96.6 percent of urban households indicated that electricity was their primary source of lighting. Only 0.1 percent of rural households and 0.4 percent of urban households indicated that they used electricity as their primary fuel for cooking. For heating, 0.4 percent of rural households and 3.2 percent of urban households cited electricity as their primary fuel.

Other uses of electricity can be deduced from appliance ownership figures derived from the ALCS. Table 2.3 below gives the percentage of survey respondents that acknowledged owning selected electric appliances (although radios are often battery operated). Communication and information/entertainment (phones, TVs and radios) rank high among urban and rural households, and cooling (electric fans) is also a priority for urban residents.

Table 2.3 Ownership of selected electricity consuming appliances

% of HH	National	Rural	Urban
Mobile Phone	66.4	58.7	90.6
Radio	40	42.3	32.8
TV	38.9	24	85.6
Electric Fan	28.7	14.7	72.7
Refrigerator	15.6	4.6	50.3
Satellite Dish	11.9	10.8	15.2
Computer	9.2	3.7	26.4
VCR	9.1	5.1	21.7

Source: ALCS

Notably, ownership of 'power hungry' appliances such as refrigerators is significantly less among rural residents than among urbanites. This might reflect smaller capacities of home-based generating systems.

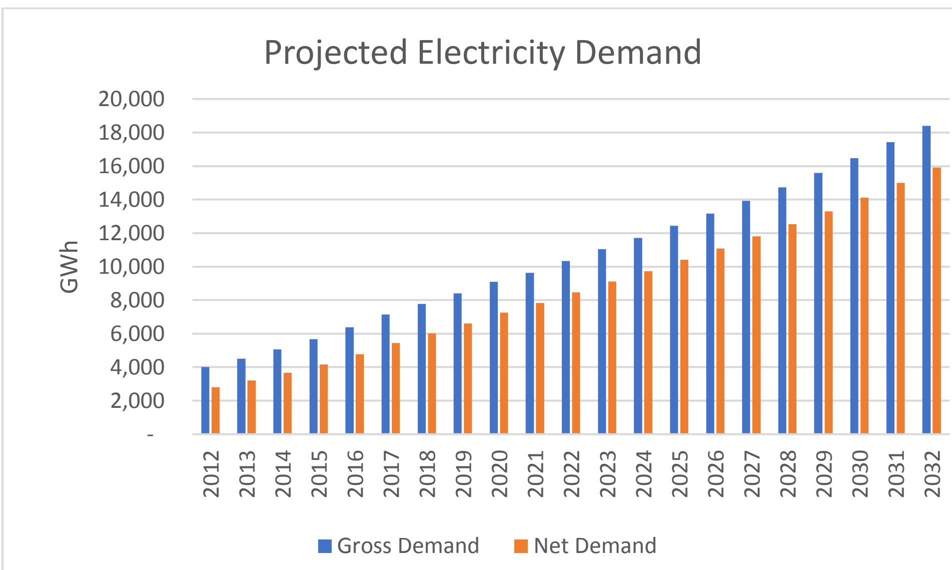
There is little data available on commercial uses of electricity. In the services sector, which comprises over half of GDP, the main uses are likely to be for lighting, computer equipment, communications and climate control. Restaurants may use electricity for cooking, but LPG dominates in home cooking and may also have the edge in commercial enterprises. In agriculture, key uses are likely to include pumps for irrigation, and lighting in storage sheds. The manufacturing sector, to the extent that it involves agro-processing, could use electricity to drive motors for conveyor belts and assembly lines, to provide refrigeration, and to provide heat for cooking, as well as area lighting and climate control. Heavier manufacturing based on minerals and other resources is most likely to use electricity for lighting and motor drives.

2.3 Projected Electricity Demand

The most recent and comprehensive forecast of electricity demand in Afghanistan was developed as part of the preparation of the Afghanistan Power Sector Master Plan (APSMP).[15] The forecast, which used 2011 consumption as a base, provided 3 scenarios for future demand for gross energy, net energy and peak demand. Figure 2.3 shows the projected gross and net energy demand for the base case. Net demand, or electricity delivered to customers, shows the steepest increase of the three variables, increasing from approximately 2,800 GWh in 2012 to 15,909 GWh in 2032, representing an average annual growth rate of 9.8 percent. Gross demand, or power sent out, increases to a lesser extent from approximately 4,000 GWh at the beginning of the period to 18,400 GWh in 2032 – an average of approximately 7.8 percent per year.

Peak demand increases from approximately 600 MW at the beginning of the forecast period to a projected 3,502 MW in 2032 in the base case or approximately 8.6 percent per year. The increase in peak load is slightly lower than the increase in gross demand owing to a projected increase in average load factor over the forecast period.

Figure 2.3 Afghanistan Projected Electricity Demand (2012 – 2032, Base Case)



2.4 Future Supply Options

The APSMP looked at a range of options for satisfying future electricity demands including medium and large HPPs, gas fired thermal plants, coal fired thermal, and imports from neighboring countries. Recognizing the GoA's desire to extend the grid-based supply system to as much of the

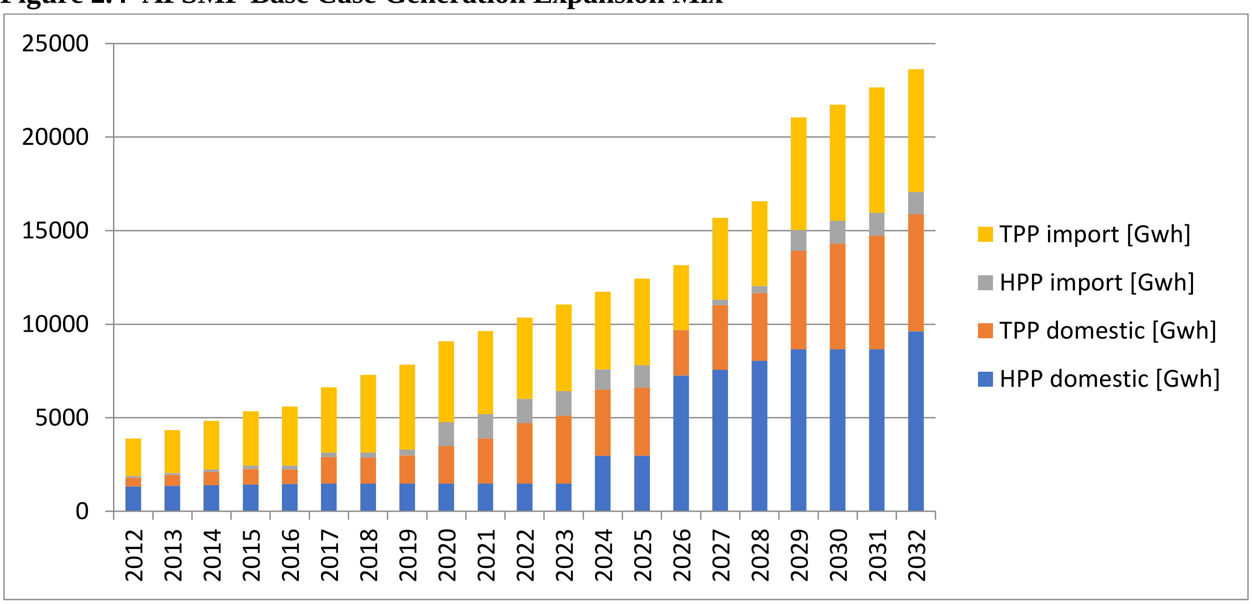
[15] Fichtner, Islamic Republic of Afghanistan, Power Sector Master Plan, Final Report, April 2013

country as was feasible, together with their interest in reducing the reliance on imports, the consultants proposed a plan that blended hydro, thermal and imports to provide grid electricity to approximately 83 percent of the population by 2032. Figure 2.4 summarizes the proposed mix of future supply. By 2032, domestic hydro would meet 41 percent of expected demand, while domestic thermal would beet 26 percent. Imports would represent 33 percent of supply, in large part to fill in for domestic HPPs whose contributions to capacity and energy requirements decline significantly during seasonal lows in the river flow.

In the base case scenario, major projects with immediate need for implementation (Stage A) focus on transmission investments to increase import capacity from Turkmenistan, moving forward with the first stage (200 MW) of a new thermal powerplant (TPP) fueled by natural gas at Mazar e Sharif, and completing feasibility studies of candidate hydro powerplant (HPP) expansion projects. They also include the first stage of providing a transmission connection between the NEPS and SEPS systems (150 MW) and connecting 17 provinces to the grid. The plan also confirms projects that were currently under way. Per the plan, these projects were to be completed by 2015.

Stage B, which extends from 2016 to 2020, envisions completion of the Turkmenistan interconnector expansion to 500 kV, as well as a second interconnector to Uzbekistan and connection of an additional 13 provinces to the grid. The third stage, Stage C, which extends through to 2025, involves the completion of an additional 200 MW of gas-fired thermal generation at Mazar e Sharif, as well as 300 MW of capacity at the Kunar B HPP. It also includes completion of an additional 150 MW of capacity on the NEPS-SEPS interconnector. The final stage, Stage D from 2026 to 2032, sees the addition of 1,200 MW of coal-fired thermal generation at Bamyan, and four new hydro: a 100 MW expansion of Kajaki HPP, the Kunar A HPP (789 MW), Olambagh HPP (90 MW), and Baghdara HPP (210 MW).

Figure 2.4 APSMP Base Case Generation Expansion Mix



The cost of imports was assumed to be constant throughout the planning period, and the availability unconstrained except by lack of transmission capacity (which was addressed as part of the investment plan).[16] Owing to the lack of other options to meet peak demands during periods of low HPP output, the least cost solutions were relatively insensitive to the assumed import tariff.

The total investment cost for the plan, broken down by stage and investment type, is shown in Table 2.4 below. Generation makes up the bulk of the investment requirements accounting for over 70 percent of the total. However, because the generation additions are stacked at the end of the planning period, 60 percent of the total investment occurs in Stage D, i.e. is post 2025.

Table 2.4 APSMP Total Investment Cost (Base Case)

US$ millions	Total	Stage A	Stage B	Stage C	Stage D
Generation projects	7,329.6	327.6	348.5	981.5	5,671.9
Major transmission projects	1,726.8	595.0	676.9	212.9	242.0
Transmission within the provinces	1,040.1	290.1	439.8	215.1	95.0
Total	10,096.5	1,212.7	1,465.2	1,409.5	6,008.9

While the APSMP proposes a significant increase in the supply of electricity through large HPPs, it does not consider other renewables as serious candidates for the generation expansion plan. However, it does note that small scale renewables might be ideal for distributed generation systems and/or mini-grids, and provides some indicative costs.

The APSMP report does not provide the assumed marginal cost of the various candidates for future generation. Table 2.5 below summarizes the estimated costs and output of proposed HPPs included in the expansion plan. The last column is an estimate of the cost/kWh assuming a 30 year life of the plant and a 10% discount rate. It should be noted, however, that the studies that formed the basis for the HPP cost estimates were out of date and incomplete in many respects. Hence the estimates of cost/kWh should be viewed with caution.

Table 2.5 – Proposed HPP Additions

First year of operation	HPP	Installed Capacity (MW)	Capital Cost ($ million)	Annual Energy (GWh)	Cost $ per kWh
Finalizing expected soon	Salma	40	200	197	0.112
Finalizing expected soon	Kajaki Extension	18.5	90	91	0.109
2024	Kunar B	300	600	1,485	0.045
2026	Kunar A	789	2,000	4,772	0.046
2028	Kajaki Addition	100	300	493	0.067

[16] Fichtner, op cit, p 10-27

2029	Olambagh	90	400	444	0.099
2032	Baghdara	210	600	968	0.068

Source: APSMP

Cost per kWh calculated by dividing annualized capital cost (10% discount rate, 25 year life) by annual output

As regards thermal additions to the network, the proposed coal fired plants were included in the Plan on the assumption that they would be located adjacent to new mines. The likelihood of these moving forward is suspect, and it is more likely that thermal additions would be fueled by natural gas. Based on data provided in relation to a proposed 50 MW gas-fired IPP at Mazar, the estimated levelized economic cost of new thermal using domestic gas is in the order of US$0.09/kWh[17].

In the period since the completion of the Plan, the GoA has adopted a policy of increased support for the development of RE generation, both grid-based and stand-alone/mini-grid. Overall the GoA proposes that approximately 10 percent of its future supply (350 – 500 MW) will come from RE resources.

[17] World Bank, Mazar IPP Project Appraisal Document (Draft), Economic Analysis Annex

3 RENEWABLE RESOURCES AND COSTS

Afghanistan's RE resources are substantial. Hydro, solar and wind resources offer significant potential for expansion either on a large or small scale. Geothermal resources also offer some potential, although they have not been extensively explored. Biomass, particularly in the form of agricultural waste, is also plentiful. While it is now used directly for heating and cooking, it could also be exploited to generate electricity. The following sections provide an overview of the RE resources available, their potential to provide additional electricity supply to the country, and current available information on their development costs.

3.1 Hydropower

Resources: With its mountainous terrain and extensive river system, Afghanistan is estimated to have recoverable hydro potential more than 23,000 MW. The vast majority of this potential (roughly 20,000 MW) is located in the north-east on the Amu Darya, Panj and Kokcha Rivers. A further 1,900 MW is located to the east of Kabul, with over half of this on the Kunar River near the border with Pakistan. Balkh and Jowzan regions in the north-west have approximately 800 MW of potential, while the remaining resources (about 500 MW) lie in the west-central part of the country. Figure A-1 in Annex A illustrates the locations of the main resources.

To date, exploitation of the hydro resource is minimal relative to its potential. As noted in Chapter II, total installed capacity as of March 2016 was 256 MW, most of which was located in the Kabul region. In mid-2016 rehabilitation works were completed at the Salma dam in Herat Province which added 42 MW to the available supply.

Development Options: With respect to specific projects, some degree of preliminary analysis has been carried out for facilities at a selection of sites. These were outlined in the 2013 Afghanistan Power Sector Master Plan (APSMP),[18] and are listed in Table 3.1, below. In most instances, the studies were out of date and some were incomplete, either missing important input data or not addressing the inter-relationships between proposed projects and other existing or potential projects in the same cascade.

Table 3.1 Potential Hydropower Projects

No	Project	River	Province	Capacity (MW)	Annual energy (GWh)	Estimated cost (US$m)	Cost (US$/kWh)
1	Baghdara	Panjshir	Kapisa/ Parvan	210	968	600	.068

[18] Fichtner, Islamic Republic of Afghanistan, Power Sector Master Plan, Final Report, April 2013

2	Surobi 2	Kabul	Lagman	180	891	700	.087
3	Kunar A (Shal)	Kunar	Kunar	789	4,772	2,000	.046
4	Kajaki Addition	Helmand	Helmand	100	493	300	.067
5	Kokcha	Kokcha	Badakhshan	445	2,238	1,400	.069
6	Gulbahar	Panjshir	Panjshir/Baghlan	120	594	500	.093
7	Capar	Panjshir	Panjshir	116	574	450	.086
8	Kama	Kunar	Nangarhar	45	223	180	.089
9	Kunar B (Sagai)	Kunar	Kunar	300	1,485	600	.045
10	Kajaki Extension	Helmand	Helmand	18.5	91	90	.109
11	Olambagh	Helmand	Uruzgan	90	444	400	.099
12	Kilagai		Baghlan	60	297	250	.093
13	Salma	Hari Rud	Herat	40	197	200	.112
14	Upper Amu	Amu Daria		1,000	4,955	2,500	.056
15	Dashtijum	Panj		4,000	19,819	8,000	.044

* Annual Capital Cost divided by annual output, where annual capital cost is based on recovery of total capital cost at a 10 percent interest rate over 25 years.

The final column in Table 3.1 shows the estimated capital cost of each project per kWh of energy produced. Costs range from less than 5 cents per kWh for Dashtijum, Kunar A and Kunar B to more than 10 cents per kWh for the Kajaki Extension and Salma. Not surprisingly, the lower costs per kWh attach to the projects with the larger outputs, although Baghdara and the Kajaki Extension are similar in cost to the much larger Kokcha project. What is perhaps surprising is that the costs per kWh, which do not include annual operations and maintenance (O&M) or major maintenance over the life of the project, are not significantly lower than the cost of imports.[19] Moreover, because the projects typically do not have extensive storage, they deliver most of their output during the April to October period, leaving the country with a capacity shortfall in the winter months, which are also the months of peak demand. Investments in HPPs to meet domestic needs therefor also require either investment in back-up thermal capacity to meet winter peaks and/or commitments on the part of neighboring countries (together with adequate transmission capacity) to provide sufficient imported power to make up the gap left by the hydros. Notwithstanding, development of the large hydro is an attractive prospect given that some of the potential projects will lessen the

[19] Import tariffs currently range from a low of US$0.02/kWh from Turkmenistan to US$0.085 from Uzbekistan. Tariffs from Iran are currently US$0.072/kWh while from Tajikistan they range from US$0.028 to US$0.04/kWh. However, imports must be paid for in foreign currency whose value may fluctuate while the capital cost of the plant will remain fixed.

need for summer imports, and in some cases, may provide surplus for export – particularly to Pakistan where peak demand occurs during the summer months.

The large hydro plants of course are only one aspect of the country's hydropower resources. Already under several support programs[20,21], the country has developed over 5,000 mini and micro-hydro plants which feed power to mini-grids located in areas not yet connected to the national grid. From a financial perspective, these developments have proven to be highly efficient, with an average cost per kW of capacity of approximately US$1,850 per kW, and $150 per family served. By comparison, the average cost per kW of capacity of the HPPs proposed for inclusion in the APSMP was just over US$2,700. The 'average' figure for power provided under international support programs, however, does not reflect the fact that most of the communities would have contributed to the development cost, nor does it take into account the fact that, unlike most other types of generation, there can be substantial differences among sites in terms of their potential cost per kW.

3.2 Solar

Resources: Most of Afghanistan lies between a latitude of 30 and 38 degrees north and 60 to 72 degrees east. With 300 days of sunshine each year, its average solar potential (Global Horizontal Irradiance or GHI) is estimated at 6.5 kWh per m^2 per day. Higher values prevail in the southern areas of Kandahar, Helmand, Farah and Herat provinces, but even in the northern provinces, where irradiance averages only 4.5 kwh per m^2 per day, electricity generation is technically feasible.[22] Total estimated national capacity based on solar radiation and feasible area is 222,000 MW.

Figure A-2 in Annex A illustrates the areas of highest and lowest concentrations of solar potential, as well as estimated total solar potential on a national scale[23]. In addition, ESMAP has recently published a Global Solar Atlas which provides detailed data and maps on solar resources worldwide. The Atlas includes a searchable database which allows the user to determine the PV

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[20] One of the primary programs is the National Solidarity Program (NSP), but other donors (e.g. GTZ, USAID) have also funded small-scale installations based on renewables.

[21] The NSP has relied on funding from a variety of sources including financing from WB/IDA and JSDF, financing from the Afghanistan Reconstruction Trust Fund (ARTF), which provides funding to NSP from various donors (Australia, Belgium, Canada, Denmark, EC/EU, Finland, Germany, Norway, Slovak Republic, Spain, Sweden, Switzerland, United Kingdom and the United States of America), and bi-lateral funding, which has come from Denmark, France, Italy, Netherlands, Czech Republic and New Zealand directly to NSP.

[22] Nagsaka/ Anwarzai (2017), "Utility-scale implementable potential of wind and solar energies for Afghanistan using GIS multi-criteria decision analysis", *Renewable and Sustainable Energy Reviews*, Vol.71, May 2017.

[23] Note that Figure A-2 shows Direct Normal Irradiance (DNI) which is most useful for assessing the potential for solar applications where the solar receptors can be maintained at an angle perpendicular to the irradiation source, such as CSP and tracking PV installations. GHI measures irradiation received by surfaces that are horizontal to the earth, and hence are likely to not be directly perpendicular to the source. It is more commonly used to assess solar PV potential.

output, Global Horizontal Irradiance (GHI) and Direct Normal Irradiation (DNI) of any geographic coordinates. The Atlas is available online at www.esmap.org/RE_Mapping. PV Output maps (kWh/kWp) and GHI Maps (kWh/m2) covering the region are included as Figures A-3 and A-4 in the Annex.

Development Options: There are two main technical options for grid-level solar plants; Solar Photovoltaic (PV) and Concentrated Solar Power (CSP). Solar PV panels convert sunlight directly to electricity using a layer or layers of semi-conductive material which release electrons when struck by light. Captured electrons create a flow of DC current which can then either be used to power DC appliances, stored in batteries, or fed through an inverter to produce AC current for use in other applications. CSP uses arrays of mirrors to focus a large area of sunlight onto a small area, thereby creating high levels of heat which is captured in a high-temperature Heat Transfer Fluid (HTF) such as synthetic oil or molten salt. The heated HTF is then used to create steam which drives conventional steam turbines to produce electricity. The thermal energy in the CSP plant can also be stored until electricity is needed.

The cost of solar PV installations has fallen dramatically in recent years. According to IRENA,[24] the installed cost of solar PV plants has dropped from a globally weighted average of US$4,394 per kW in 2010 to US$1,388 per kW in 2017 – a decline of 68 percent. They attributed the decline to a combination of increased competitive procurement and continuing technological improvements. The cost of solar PV modules fell by 80 percent from 2010 to 2016,[25] and now typically represents less than half of the total installed cost. Balance of System (BoS) including inverters, cabling and wiring, installation costs and soft costs such as design, financing and permitting constitute the remainder[26] and represent the area with the greatest potential for further cost reductions. The global average levelized cost of electricity (LCOE) of utility-scale solar PV fell by two-thirds between 2010 and 2017 from US$0.36 per kWh to US$0.10 owing to both the drop in installed costs and rising plant capacity factors. IRENA noted that "the weighted average LCOE by region for utility-scale solar PV projects that were installed in 2016 and 2017 ranged from a low of around US$0.09 per kWh in Asia to a high of US$0.17 per kWh in Eurasia. In Central America, the Caribbean and South America the average was US$0.13 per kWh"[27] Cost differences among regions can be attributed to site-specific issues such as difficulty of access or low levels of radiation or to system issues such as low plant capacity factors.

Looking ahead, this downward cost trend is expected to continue. Published information on bids to install solar facilities, either directly negotiated or offered in auctions, suggests that prices for projects that will be commissioned between 2018 and 2020 will fall to below US$0.06 per kwh.[28]

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[24] IRENA, *Renewable Power Generation Costs* in 2017,January 2018, p. 41
[25] Ibid, p. 61
[26] Ibid, p. 67
[27] Ibid, p. 41
[28] Ibid, p. 49

Published auction prices are not necessarily a reliable indicator of absolute levels, since the contract arrangements may include or exclude items which would normally be covered in the calculation of LCOE (escalation factors, in-kind buyer contributions, capacity charges, etc). However, the trend is decidedly downwards.

Residential level PV systems such as those that might support a mini-grid or even single user have also experienced substantial price drops in the recent past as the costs of solar panels has fallen. For example, based on the assumption of a 5 percent cost of capital, the LCOE of residential PV systems in Germany declined 56 percent between 2010 and 2017 from US$0.30 to US$0.15/kWh. Data since 2013 from India, China, Australia and Spain shows that in these countries, which have better irradiation conditions, and where installed costs have become increasingly competitive, lower LCOEs than the German example can be achieved even if installed costs are sometimes higher. In these low-cost markets, the LCOE range was between US$0.15 and US$0.20/kWh in 2013, falling to between US$0.08 and US$0.12/kWh in 2017, a decline of between 34% and 45% during the period.[29] Increasingly, home based systems are becoming competitive with grid supply.

Table 3.2 shows recent prices for different types of solar modules in Afghanistan. Typically, these costs would not include BoS items such as inverters (to convert DC to AC), batteries for storage in off-grid systems, and various hard and soft costs associated with installation. These BoS costs can exceed US$1,000 – 1,500 per kW.

Table 3.2 Solar PV power products and cost in Afghanistan

Product	Power Level	High-end Product (US$)	Low-end Product (US$)
Solar lantern	1.5-3Wp	NA	6-18
One light & phone charging	3-5Wp	NA	20-25
Small home solar system	20Wp	100-120	70-80
Medium home solar system	80-100Wp	300	150-200
Large home solar system	150-200Wp	400-450	250
Very large home solar system	300Wp	600-800	400-450
Home solar hybrid system	1 kWp	2400-2600	1000-1200

Source: Afghanistan Off-Grid Solar Lighting, Market Scoping, 2015, p. 14

CSP is at a much earlier stage of development relative to Solar PV technologies but is gaining in popularity as it has the ability to store energy (in thermal form) and deliver it to the grid during periods of peak demand. Installed costs averaged US$5,564 per kW in 2017, as compared with US$7,583 in 2010[30]. The average LCOE in 2017 was US$0.22 per kWh as compared with US$0.33 per kwh in 2010. However, this is expected to decline sharply in the near future, with auctions

[29] Ibid, p. 71
[30] Ibid, p. 46

prices in Dubai and South Australia coming in at US$0.07 and US$0.06 per kwh respectively.[31] According to a 2013 report prepared for the World Bank, there is room for economies of scale in the production of mirrors or heliostats, and for efficiency improvements including (i) higher temperature HTFs; (ii) improved or new designs for components of the solar system to improve optical performance; (iii) improved efficiency of the power generation process; and (iv) increased automation and control to optimize the plant's operation.[32] The same report predicted that CSP costs would decline by 7 percent per year between 2012 to 2017, by 3 percent per year from 2017 to 2025 and by 1% per year from 2025 to 2035.

3.3 Wind

Resources: Afghanistan's wind resources are also substantial, but highly localized. Figure A3 in Annex A shows the overall estimated exploitable capacity and the areas of greatest potential. In all, the country's total capacity is estimated at approximately 150,000 MW, based on total 'windy area', that is, the area where average wind speeds exceed 6.8 m/s, which is generally considered to be a threshold for viable projects. Exploitable capacity is estimated to be roughly 66,700 MW. It is estimated that total installed capacity of wind power is about 300 kW with the largest wind power system of 100 kW (a diesel/battery/inverter system) in the mountainous province of Panjshir.[33]

Figure A-5 in Annex A provides a map of the country's wind power potential in total MW. Figures A-6 and A-7 provide additional detail on wind power (W/m2) and average wind speed (m/s) in the region. There is exploitable wind potential near existing hydropower plants such as Kajaki and Naghlu, and in the eastern provinces of Zabul and Nangarhar, and the northern regions including Baghlan, Takhar, Sari Pul, and Faryab provinces.[34] However, seventy-five percent of the 'windy area' and 90 percent of the exploitable capacity are located in three provinces, Herat, Farah and Nimroz all of which are in the west-central part of the country. Herat has transmission links from the capital to both Iran and Turkmenistan, but it is isolated from the rest of the transmission network. Nimroz, like Herat, is connected to Iran, and receives power at the 20 kV level. However, it has no transmission connections to other provinces. Farah has no connections either to the Afghanistan network or to Iran. Its power supply is limited to a few isolated mini-grids and individual systems. Given the isolation of the wind resources, substantial capital investments in transmission lines and substations will be needed to connect new wind farms even to local load centers. For the wind energy to be evacuated to the rest of the country would require

[31] Ibid, p. 51
[32] AF Mercados EMI, Sun to Market Solutions, "Concentrated Solar Power (CSP) in the Middle East and North Africa Region: A Review of Issues and Options", prepared for the World Bank and ESMAP, May 2013, MI1384
[33] The Inter-Ministerial Commission for Energy Secretariat (2016), *Wind Energy* https://sites.google.com/site/iceafghanistan/renewable-energy/wind-energy
[34] Nagsaka/Anwarzai (2017), "Utility-scale implementable potential of wind and solar energies forAfghanistan using GIS multi-criteria decision analysis", *Renewable and Sustainable Energy Reviews*, Vol.71, May 2017.

interconnection of the currently isolated Herat network to other parts of the existing transmission network, either by constructing a link to the Northeast system in Faryah Province and/or by building a link to the Southeast system at Kandahar.

Development Options: Costs of onshore wind installations have varied over recent years. The technology is relatively mature and can accommodate a wide range of physical and wind speed conditions, as well as plant utilization factors which tends to improve efficiency at any given installation. However, the main cost component is the wind turbine, which is affected primarily by the cost of commodities (steel, cement) necessary to build it. As these have fluctuated, turbine costs and hence the total costs of wind capacity have moved upwards and downwards. Data on a number of projects that were to be installed in 2014 suggested an average total capital cost of US$1,779 per kW. However, there was significant variation among regions, with costs in China and India of US$1,310 – 1,370 per kW, while costs in 'Other Asia' averaged around US$2,560 per kW[35].

Capital cost of the wind farm, including turbines, grid connections, civil works and various soft costs are a major determinant of the LCOE for wind power. However, the quality of the wind resource, the related compatibility of the installed turbines, and the costs of operations and maintenance an also play a major role in determining the average cost per kWh. Like all capital-intensive projects, the cost per unit of output of wind power installations is highly sensitive to the level of output since most of the costs are unrelated to volume. According to IRENA, in 2016/2017 the average LCOE for onshore wind power in OECD countries was US$0.065 per kWh. Costs in Asia and the rest of the world were fractionally higher.[36] The global average installed cost of utility scale onshore wind projects was US$1,477 per kW in 2017.[37] According to IRENA's auction database, by 2019 the best solar PV and wind projects will be providing power for as little as US$0.03 per kWh.[38]

3.4 Geothermal

Resources: While there are indications that Afghanistan possesses significant geothermal potential, there have not been any detailed surveys of the location or full extent of the resource. Numerous mineral springs have been used for therapeutic purposes, purportedly for several centuries, and in the past century infrastructure has been developed around some, but their potential for the supply of energy does not appear to have been evaluated until more recently. A paper presented in 2004 assessed the geothermal potential based on the geological structure of the region, and on the existence of areas with surface water temperatures higher than 20˚ C. The paper

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35 Ibid, p. 61
36 Ibid, p. 48
37 Ibid, p. 94
38 Ibid, p. 56

identified active geothermal systems mainly along the main axis of the Hindu Kush, along the Herat fault system, from Heart in the west, up to the Wakhan corridor in the northeast.[39]

More recently, a group of scientists analysed the findings of an aeromagnetic survey that was carried out by the US Geological Service (USGS) and the Afghanistan Geological Service (AGS)[40]. The aeromagnetic data was used to estimate the depth of the earth's magnetized crust over the western part of Afghanistan, and by inference to determine the rate of change in the underground temperature (geothermal gradient). The resultant maps offer guidance as to the locations of geothermal potential and the extent of the resource in each area, and provide a method for identifying areas that merit more detailed investigation.

Development Options: Geothermal power generation, while not widespread, is a mature process that can offer low cost base-load power provided the geothermal resource is adequate and can be accessed at moderate cost. There are two main types of plants; 'flash' plants, which require high temperature hot water resources and utilize the hot water directly to create steam, and 'binary' plants which are used with moderate temperature resources and use a heat exchanger to heat a liquid with a low boiling point to create steam. Binary plants typically have higher capital costs and lower operating efficiencies than the flash plants. Capital costs for both types of plant are driven by commodity prices for materials and by drilling costs which are closely tied to prices for oil and natural gas. In 2009, the total installed cost of flash plants ranged from US$1,900 to 3,800 per kW, while binary plants ranged from 2,250 to 5,500 per kW.[41] According to the US Department of Energy, the cost of large scale plants is estimated at US$2,500 per kW, while smaller installations (< 1 MW) would range from US$3,000 to 5,000 per kW.[42] Typically the power plant is the costliest part of the installation, but drilling of the production and re-injection wells is also significant, especially if initial drilling efforts are unsuccessful.

The LCOE of geothermal power plants is largely a function of capital cost and plant capacity factor (which can be quite high as the plant can run continuously except for maintenance outages). However, the geothermal resource needs to be carefully managed in order to optimize, and potentially to sustain its performance over the plant's lifetime. According to IRENA, recent greenfield installations cost in the order of US$0.14 per kWh, while plants scheduled to come on line between 2015 and 2020 were typically projected to have LCOE's of US$0.06 to 0.12 per kWh, although there is no assurance that actual costs will match projections.[43]

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[39] Saba, D.S.,Najaf, M.E., Musazai A.M., S.A. Tarak, S.A. (2004, February). *Geothermal Energy in Afghanistan: Prospects and Potential, Center on International Cooperation*, New York University, New York & Research Institute for Economic Development and Social Policy, Kabul.

[40] H. Saibi, E. Aboud, M. Azizi, *Curie Point Depth Map for Western Afghanistan Deduced from The Analysis Of Aeromagnetic Data*, presented at the World Geothermal Congress 2015, Melbourne Australia

[41] IRENA, op cit, p 139

[42] Website of the US Department of Energy, Office of Energy Efficiency and Renewable Energy, https://energy.gov/eere/geothermal/geothermal-faqs#geothermal_energy_cost

[43] IRENA, op. cit, p 142

3.5 Biomass

Resources: Biomass is already used extensively in Afghanistan for home heating and for cooking. The primary resources available are crop residues, animal manure, firewood, and municipal waste. According to the ALCS, 74 percent of all households and 90 percent of rural households relied on biomass as their primary fuel for cooking, while 82 percent of households and 90 percent of rural households used is as their primary source of heat. Normally the biomass is burned in open stoves, which causes pollution from particulates and potential health problems. Consideration might therefore be given to using this biomass to generate electricity rather than as a direct source of heat energy.

Figure A-8 in Annex A contains a series of maps showing the location, extent and generating potential of the country's biomass resources, based on a review carried out in 2011.[44] The electricity generating potential is estimated to total over 4,000 MW, including 3,092 from crop residue, 841 from animal manure and 94 from municipal solid waste. Firewood was not considered to be an option as the country's forest resources are already seriously depleted. The study identified biogas generation from animal manure and waste-to-energy (WTE) from urban discards as the most promising sustainable biomass technologies using existing resources in Afghanistan. Biogas technology is more applicable to rural regions and WTE is best suited for urban areas. While the volume and energy content of crop residues is substantial, most of the agricultural activity is at the household level for own use or local markets. Thus, it would be difficult and costly to amass the large volumes needed to support power generation at an economically viable scale.

While biogas digesters produce gas rather than electricity, the gas can be used as an alternative to electricity for cooking, heating, lighting and even refrigeration. Digesters can be built in a range of sizes to serve either a single family (3 – 4 persons) or an extended group (18 – 24 persons). In total, the study estimated that, based on the number of livestock in the country, almost 900,000 households could be provided with sufficient biogas to meet their cooking and lighting needs.

WTE technology is a useful way both to manage and dispose of solid waste in an environmentally safe manner and also to generate electricity. Kabul, Kandahar, Herat, Mazari Sharif, and Jalalabad are centers with large concentrations of waste that could be used as an energy source.

Development Options: The costs of electricity produced by biomass will depend on the nature and availability of the biomass resource and of the technology chosen for the power plant. While the biomass feedstock itself may be very low cost, it also typically has a relatively low energy

[44] A. Milbrandt, R. Overend, *Assessment of Biomass Resources in Afghanistan*, National Renewable Energy Laboratory, January 2011

density. As a result, transport costs per unit of energy delivered can be extremely high, and plants are best located close to the source of the feedstock. The feedstock also needs to be converted into a form of energy that can be used to produce electricity. The most common are direct combustion to produce heat, either in a dedicated boiler or in combination with some other combustible material, and digestion to produce biogas.

Capital costs for biomass power plants vary widely depending on size, type of fuel, and almost US$8,000[45]. Plants in developing countries are at the low end of the cost range, with technology. Installed costs in 2014 ranged from a low of approximately US$500 per kw to a high of installations in Asia and South America ranging in cost from US$ 450 to 2,000 per kW. LCOE's for biomass power generation vary widely with the type of plant, type and cost of feedstock, plant efficiency and plant capacity factors. In Asia, the weighted average LCOE is about US$ 0.04 per kWh in India and US$ 0.05 per kWh in China. By comparison, costs in OECD countries average US$ 0.085 per kWh in line with higher costs of feedstock, stringent emissions standards and more sophisticated technologies.[46]

[45] IRENA, op cit, p 131
[46] Ibid, p. 134

4 INTEGRATING RENEWABLES INTO SYSTEM DEVELOPMENT PLANS

Planning for the integration of RE into the future generation plan for a country presents some unique challenges. Generally traditional planning models which attempt to optimize, in terms of size and timing, among a range of generation options are not well suited to evaluating resources whose cost effectiveness can vary widely depending on location and market density. Some attempts have been carried out in Afghanistan to determine the most appropriate roles for renewables, including hydroelectricity, utility scale solar and wind, and off-grid solar and wind options. While the value of some of this work is limited by the poor quality of the input data, the exercise has been helpful in identifying some of the challenges of planning for renewables, and the outcomes provide some useful insights.

4.1 System Master Planning Models

Traditional power system planning techniques start with a projected level of demand to be satisfied and a range of supply options. Normally the supply options are independent of one another, and are fully dispatchable. They typically include a variety of types of thermal technology and a range of fuels. Except for differences in the costs of capacity and energy associated with each technology, they are interchangeable. Repeated application of the model generates a least cost plan for the addition of sufficient new generation to meet future demands. Some models also allow the analyst to include a selection of hydroelectric plants, although these can complicate the analysis as they are typically location specific (which has implications in terms of transmission costs) and may produce a combination of firm and non-firm energy, which complicates the costing of their outputs. Afghanistan's current Power Sector Master Plan (APSMP)[47], which was developed in 2013, was based largely on traditional power system planning techniques and models. WASP (Wien Automatic System Planning) is perhaps the best known and most widely applied of these, but many agencies have adopted modified versions to meet their own specific needs.

Non-cost criteria can also be imposed on the planning models. In the case of the APSMP, for example, the analysis sought to maximize the degree to which demand was satisfied by domestic sources – thereby granting a benefit to security of supply. Hence, new national generating plants might be favoured over increased imports even if the imports were projected to be less costly.

Most renewable energy sources are difficult to integrate into the traditional generation planning models for several reasons. Like hydroelectric plants, many are location specific. Wind and geothermal, for example, must be located close to what are often geographically limited resources. Solar plants are generally more flexible, but even within a small country, there will be areas where the resource availability is greater and the cost per unit of output is correspondingly less. Cost

[47] Fichtner, *Islamic Republic of Afghanistan, Power Sector Master Plan, Final Report*, April 2013, Asian Development Bank

differences related to location mean that alternative generating options are not inter-changeable and hence cannot easily be compared to other (e.g. thermal) options or even to each other. In addition, if selected for inclusion in the plan, they might impose constraints on the transmission network that will be needed to deliver the electricity to markets, which leads to further variations in their unit cost. Finally, renewables such as wind and solar – which are the most advanced and least costly options for Afghanistan – cannot deliver firm energy unless extensive and often costly storage is available (battery banks, pumped storage, etc). If they are to be comparable to other generation options, they must be a part of a system where alternative sources of energy are available to meet demands when the renewable resource is unable to supply. If this is not the case, the cost of the renewable option must either be adjusted for the cost of storage or for the cost of unmet demand.

The APSMP includes an assessment of the potential role of large hydropower plants (HPP) in the optimal generation mix, although it concedes that some of the input data were suspect. In this regard, it presents a plan for future integration of utility scale HPPs into the development plan. However, it does not address any possible grid-based role for other RE resources. Large scale renewables may have been omitted because at the time their costs were prohibitively greater than the costs of other (mainly thermal) technologies. Alternatively, they may have been omitted because of the difficulties cited above in incorporating their multiple unique characteristics into a generalized planning model. It should still be possible, however, to manually incorporate a selection of grid-scale renewable options into the Plan, and assess the cost implications as compared with the cost of traditional options that they would replace. If the costs (including transmission impacts) are lower, the findings favour their inclusion. However, even if the costs are higher, other benefits (environmental, technical) may weigh the decision in favour of the renewable option.

Unfortunately, the APSMP as it now exists would require some adjustment before it could be used as a basis for integrating more renewable energy into the power system expansion sequence. To date, progress on implementing the proposed investments is seriously lagging. Salma Dam and the Kajaki HPP Expansion projects were intended to be completed by 2015 but were only commissioned in late 2016. Major transmission investments, including a new line from Turkmenistan and an interconnector between the NEPS and SEPS, which were also scheduled for completion by 2015, are still under construction. The Plan also foresaw 200 MW of gas-fired thermal generation at Sheberghan by 2020 and a further 200 MW by 2022, but at present the only plans are for a 50 MW IPP, and the financing and contractual frameworks for this plant are still being negotiated.

While the delays in implementation mean that the investment plan requires some amendment in terms of timing, there have been equally severe shortfalls in the growth of parameters underlying the demand forecast. The demand forecast on which future demand for energy was based assumed

GDP growth of approximately 6 percent per annum from 2012 to 2018, and 4 percent per annum thereafter. According to IMF data, however, actual GDP growth fell from 13.9 percent in 2012 to 2.7 percent in 2014, 1.3 percent in 2015, and 2.4 percent in 2016. Estimated GDP growth in 2017 is 2.5 percent[48]. Compound growth rate from 2011 to 2016 was 28 percent whereas the forecasts in the APSMP were based on a compound growth of 35 percent. The gap will continue to widen as the APSMP projected growth rates of 6 percent per annum in 2017 and 2018 whereas current estimates are less than half that. Since the income elasticity of demand was assumed to be 1.1 for residential customers and 1 for commercial and industrial users, the APSMP demand forecasts are substantially overstated as compared with what actual income growth figures would imply.

One possible starting point for the integration of grid-scale renewables into the APSMP would be to look at renewables as a possible replacement for part of the planned – but not yet funded - gas fired thermal installations at Sheberghan. The proposed siting and technology would have to meet several criteria. For example, it would have to have at least the same level of grid connectivity as the Sheberghan plant (and any incremental transmission requirements would have to figure in the costing), and it would have to have adequate backup in place to ensure that it could meet its full share of demand. This backup would also have to be costed, although there is substantial diesel fired thermal capacity in the country which, while not currently used owing to the high cost of fuel, might be economically viable as a backup to ensure reliability. The calculated cost of the renewables-based generating plant could then be compared to the calculated cost of the thermal plant that it would replace, and its attractiveness judged both on the basis of computed cost and on the basis of cost adjusted for other benefits.

4.2 Geospatial Analysis for Project Identification and Ranking

Given the difficulties with integrating RE options directly into system planning models, a more common approach has been to define a target in terms of the amount of RE in the generation mix. The sophistication of optimization models is lost, but in most cases RE is justified on the basis of environmental benefits regardless of its possibly higher cost. Having determined that a particular quantity of RE-based generation should be provided, the question then becomes how big should individual installations be and where should they be located.

The WB team in Afghanistan recently carried out an exercise to identify and rank areas suitable for the development of utility scale solar photovoltaic plants and wind farms. The study used GIS maps and data, and a set of tools specifically developed by the Lawrence Berkeley National Laboratory to identify the potential project areas.

The methodology consisted of three stages:

[48] International Monetary Fund, World Economic Outlook Database, December 2017

i) Identification of all viable land by applying exclusion criteria;
ii) Division of the included areas into spatial units, representing potential sites;
iii) Calculation of area attributes and levelized cost of electricity (LCOE) for each potential site.

Identification of viable land: This stage excluded all land areas not suitable for development of RE facilities because they did not satisfy a set of environmental, social, geographic and natural hazard constraints. For example, areas with population density higher than 200 people per square kilometer, or with a slope steeper than a certain threshold, etc., were deemed unsuitable for development and excluded from further analysis. Other areas were excluded based on existing land use or land cover. Table 4.1 summarizes the list of inclusion criteria for different types of site characteristics. Table 4.2 lists the criteria used to determine inclusion or exclusion of land based on land use and land cover types.

Table 4.1 List of exclusions to define site suitability areas

Parameter	**Inclusion criteria for PV**	**Inclusion criteria for Wind**	**Unit**
Lakes	Value >= 500	Value >= 500	Distance in meters
Rivers	Value >= 500	Value >= 500	Distance in meters
Slope	Value <= 10	Value <= 25	Slope in percentage
Elevation	Value <= 4000	Value <= 4000	Elevation in meters
Protected Areas	Value >= 500	Value >= 500	Distance in meters
Land Use/Land Cover	Value > 0	Value > 0	Distance in meters
Airports	Value >= 2000	Value >= 2000	Distance in meters
Airfields	Value >= 100	Value >= 100	Distance in meters
Population	Value <= 200	Value <= 200	Density per square km
Bedrock landslides in slow evolution	Value <= 4	Value <= 4	Susceptibility (min 0 – max 8)
Bedrock landslides in rapid evolution	Value <= 4	Value <= 4	Susceptibility (min 0 – max 8)
Cover material landslides in rapid evolution	Value <= 4	Value <= 4	Susceptibility (min 0 – max 8)
Earthquake	Value <= 0.2	Value <= 0.2	Peak Ground Acceleration (g)
Flash flood	Value <= 4	Value <= 4	Susceptibility (min 0 – max 8)
Fluvial flood	Value <= 0.5	Value <= 0.5	Water depth in meters

Avalanche	Value <= 3	Value <= 3	Impact pressure in kPa

Table 4.2 List of LULC exclusions to define site suitability areas

Land Use Land Cover Class	Inclusion Criteria
Rangeland (grassland/forbs/low shrubs)	Included
Irrigated: Intermittently Cultivated	Excluded
Irrigated: Intensively Cultivated (1 Crop/Year)	Excluded
Rainfed Crops (sloping areas)	Excluded
Rock Outcrop / Bare Soil	Included
Marshland Permanently inundated	Excluded
Fruit Trees	Excluded
Rainfed Crops (flat lying areas)	Excluded
Settlements	Excluded
Natural Forest (closed cover)	Excluded
Natural Forest (open cover)	Excluded
Irrigated: Intensively Cultivated (2 Crops/year)	Excluded
Degenerate Forest/High Shrubs	Excluded
Water Bodies	Excluded
Permanent Snow	Included
Marshland Seasonal	Excluded
Vineyards	Excluded
Sand Covered Areas	Included
Sand Dunes	Included
Pistachio Forest	Excluded
Gardens	Excluded

As additional exclusion criteria, minimum thresholds were applied to the Global Horizontal Irradiance (GHI) and wind resource. Areas where GHI was lower than 4 kWh per m^2 per day were excluded from the PV calculation, and areas where the mean wind speed was lower than 5 m/s were excluded from the wind calculations. Data on wind and solar potential has been incorporated in a Geographic Information System (GIS) format. The GIS resource database includes high-resolution (5-km) annual wind power maps and high-resolution (900 m) annual and seasonal solar resource maps. These resource data allow the user to examine the resource together with other key information including population, load centers, transmission corridors, generation facilities, terrain and land use, and the like.

All data were transformed to 90 m x 90 m grid size. Land use efficiency factors (in MW per km^2) were applied for each technology to estimate the resource (in MW). The following land use efficiency values were used: Wind: 9; Solar PV: 30. In addition, a land use discount factor was applied, reflecting the fraction of all suitable land areas that should be considered in the estimate of the resource (in MW). This factor represents the uncertainty in the development of the resource on identified sites due to additional socio-economic, cultural, or physical constraints not captured by the input data. The land use discount factor values which were used are as follows: Wind: 75%; Solar PV: 90%.

***Division of the included areas into spatial units*:** In this stage, all land which met the inclusion criteria was divided into spatial units, also called 'Project Opportunity Areas". The size of each spatial unit was roughly comparable to the extent of a utility scale wind or solar power plant. For the base cases, simulations were performed to produce spatial units equal to 2 km x 2 km.

Calculation of area attributes and LCOE for each potential site: Several attributes were calculated for each spatial unit (see Table 4.3).

Table 4.3 Area attributes

Distance from closest transmission line
Identity of closest transmission line point
Distance from closest substation
Identity of closest substation
Distance from closest road
Distance from closest planned solar PV project
Distance from closest load center
Distance from closest water body
Mean elevation
Mean slope
Mean population density
Mean susceptibility to bedrock landslides in slow evolution
Mean susceptibility to bedrock landslides in rapid evolution
Mean susceptibility to cover material landslides in rapid evolution
Mean seismic hazard (probability of Peak Ground Acceleration)
Mean susceptibility to flash flood hazard
Mean fluvial flood hazard (probability of water depth)
Mean avalanche hazard (probability of impact pressure)
Mean global horizontal irradiance
Mean wind power density
Mean wind speed
Mean capacity factor
Average annual electricity generation
Average levelized cost of electricity (in US$/MWh) for interconnection to transmission line component
Average levelized cost of electricity (in US$/MWh) for interconnection to substation component
Average levelized cost of electricity (in US$/MWh) for road construction component
Average levelized cost of electricity (in US$/MWh) for generation component
Average total levelized cost of electricity (in US$/MWh) if interconnected to transmission line

Average total levelized cost of electricity (in US$/MWh) if interconnected to substation

The capacity factor for solar PV was estimated as the ratio of the GHI, adjusted for inverter and AC wiring efficiencies and outage rates, to an assumed incident power density of 1000 W per m^2. The capacity factor for wind energy was estimated as the ratio of the mean wind power output after accounting for collection losses and outages to the rated power output of the turbine, which was assumed to be 2,000 kW.

The levelized cost of electricity (LCOE) describes the average cost of electricity for every unit of electricity generated over the lifetime of a project at the point of interconnection. The LCOE was been calculated as the sum of three components:

- **LCOE - generation** includes capital cost, fixed and variable operation and maintenance costs. Capital costs for Solar PV installations are based on current global averages (US$1,400 per kW), although sensitivity analyses were also carried out for lower cost levels. Capital costs for wind technology include financing, balance of station costs, and turbine costs, and varies across different IEC turbine class (IEC is the International Electrotechnical Commission which publishes wind turbine standards). The analysis has been conducted for the lower wind speed Class III turbines, which typically have higher hub heights and larger rotors compared to Class II turbines, resulting in higher capacity factors but also higher capital costs because of the larger rotors. The decrease in LCOE for Class III turbines due to the higher capacity factor is thus less dramatic as it is balanced by a corresponding increase in capital costs due to the larger rotor.

- **LCOE - interconnection** includes the cost of building a transmission line from the project site to the closest electrical grid point, as well as the cost of two substations. In this analysis, the cost of transmission was assumed to be a function of its length alone, therefore assuming the cost independent of voltage, capacity of the line, type of conductor, structure of the poles, terrain, and right-of-way, as well as location or region-specific factors such as financing and material costs. A more accurate estimate of transmission costs should account for the above factors.

- **LCOE - road construction** was estimated using a fixed capital cost per km of additional road needed to service the project, and is expressed per unit of electricity output from the project. Road capital costs was assumed independent of the size of the project, and was calculated assuming 50 MW of capacity per project opportunity area regardless of its size.

Because of the high variability of the costs due to regional and temporal factors, and a dynamic industry, the LCOE estimates are better suited to be used to compare costs within a single technology. System integration costs or balancing costs are not included in the analysis. Also, the estimated LCOE does not reflect the variation of the value of electricity generated by different technologies at a given location. Generation at different times of the day or year also has a different economic value depending on the demand and the available generation at that time.

Results: The following figures show examples of some of the maps generated by the analysis. All the figures are generated from the results of the simulations with spatial units equal to 2 km x 2 km. In general, the results clearly indicate that the country has a large potential for both solar and wind development, with large opportunity areas mainly located in the southern and western provinces. The LCOE maps show costs of generation only and as such under-state the full cost of energy. Costs for roads and connection to a substation would need to be added in order to assess the full supply cost. However, these costs are location specific and are also subject to considerable uncertainty as there are numerous planned but as yet incomplete investments in the country's infrastructure whose implementation (or lack thereof) would affect the total LCOE.

Figure 4.1 shows the estimated annual solar generation per spatial unit for those areas of the country which met the criteria for inclusion in the analysis (as described in Tables 4.1 and 4.2, as well as the threshold levels for GHI. The Figure indicates that the generation potential of spatial units identified as suitable ranges from a low of 8,128 MWh per year in the green shaded areas to a high of almost 25,000 MWh per year in the areas shaded in red. The average (mean) generation potential of all areas identified as suitable is estimated at 20,599 MWh per year.

Figure 4.1 Average annual solar PV generation (MWh/year) per spatial unit estimated using capacity factor, land use discount factor, and land area.

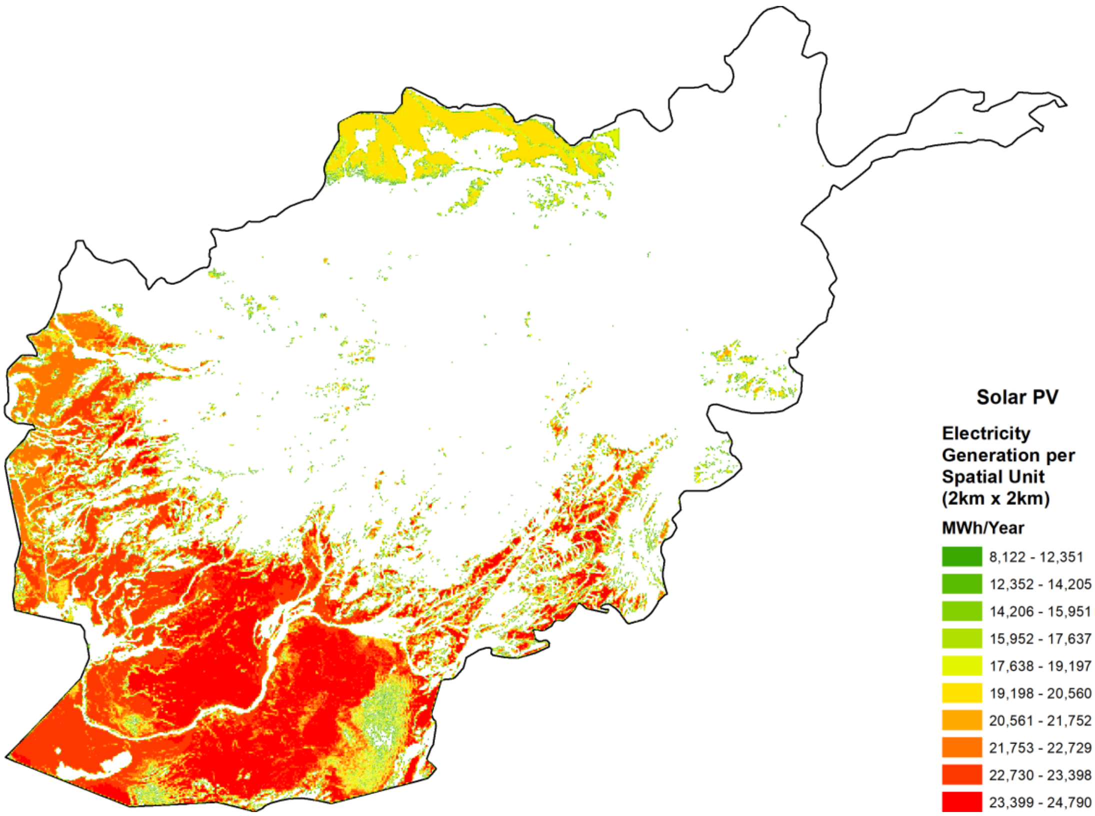


Figure 4.2 shows the total levelized cost (LCOE) of solar PV generation for the spatial units with the potential to accommodate grid-level (in this case 50 MW capacity) solar installations. Not surprisingly, the areas with the lowest potential output as shown in Figure 4.1 also tend to show the highest cost per kWh. Unit costs range from a low of US$ 0.097 per kWh in the southern and southeastern parts of the country to a high of US$ 0.137 per kWh, mainly in the northwest.

As noted earlier, the costs shown in Figure 4.2 do not include the costs of connecting a new plant either to the road network or to the transmission system. These costs can add in the order of 20 percent to the base cost of the plant, although the increment could be higher or lower depending on the proximity and extent of existing facilities.

Figure 4.2 Total levelized cost of solar PV (LCOE) - generation only

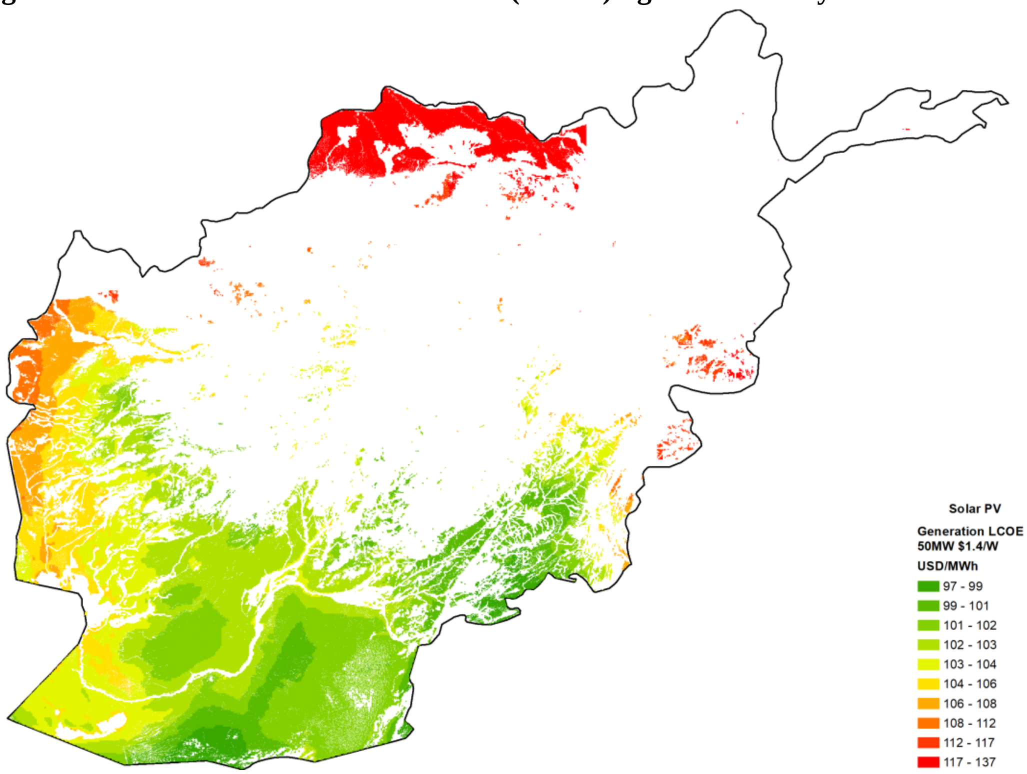


Figure 4.3 shows the average annual wind generation capacity of each 2 x 2 km spatial unit designated as suitable for wind installations (again based on the criteria in Tables 4.1 and 4.2 and the threshold mean wind speed). In this case the annual generation capacity per spatial unit ranges from a low of just under 3,000 MWh per year to a high of just under 100,000 MWh per year in some small areas in the western part of the country near the Iranian border. The mean generation potential of all areas identified for inclusion is estimated at 21,285 MWh per year.

Figure 4.3 Average annual wind energy generation (MWh/year) per spatial unit estimated using capacity factor, land use discount factor, and land area.

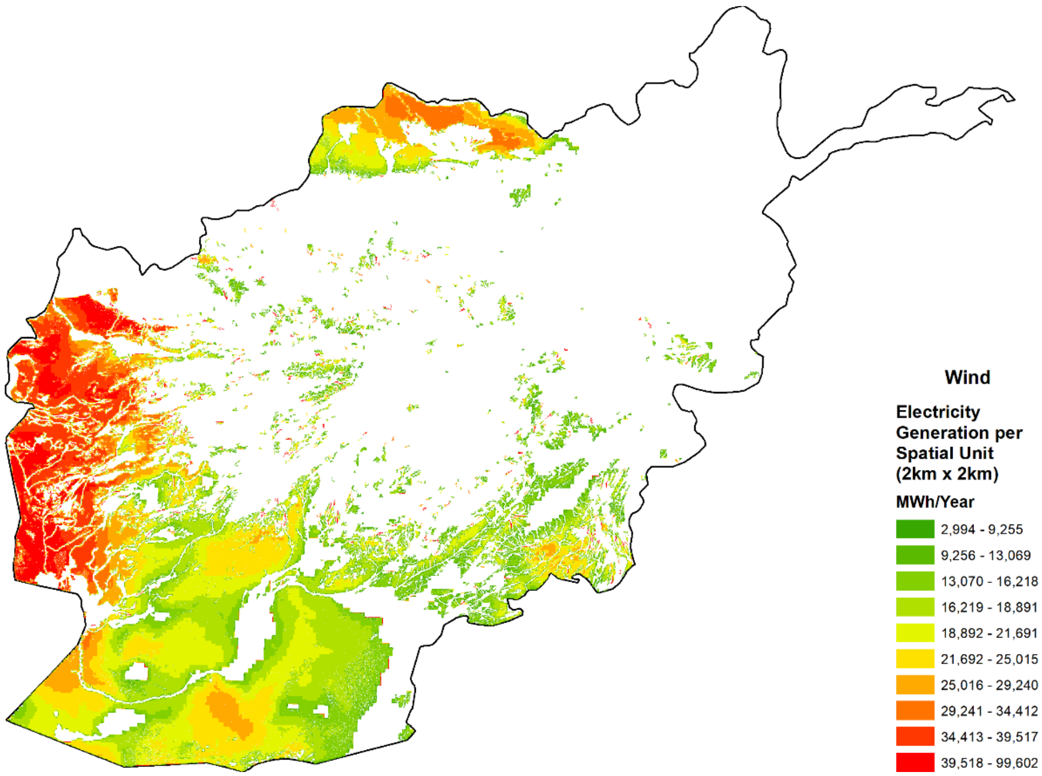
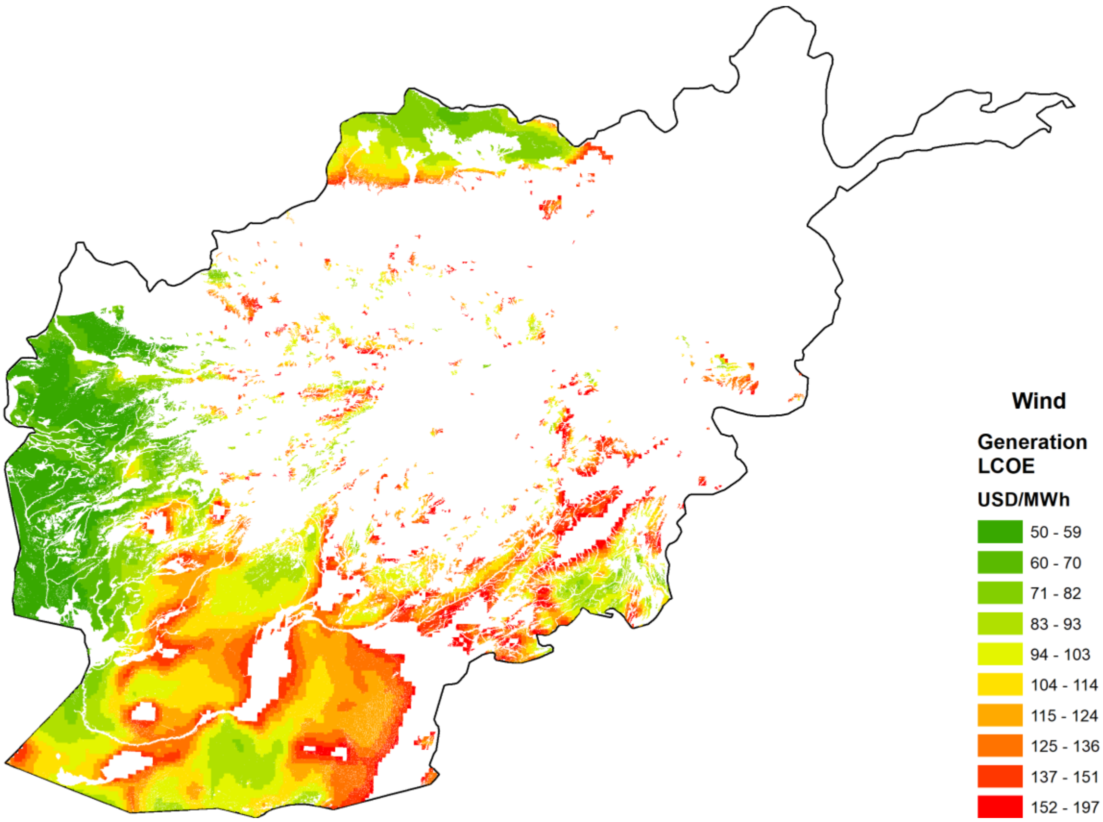


Figure 4.4 illustrates the LCOE of wind generation in the identified areas. Costs of generation range from a low of US$0.050 per kWh to a high of US$0.197 per kWh.

As with solar PV, it is necessary to add in the costs of road and substation interconnection to the generation costs in order to assess the full cost of wind energy. While these costs will vary among locations, they are likely to add between 10 and 20 percent to the cost of the facility.

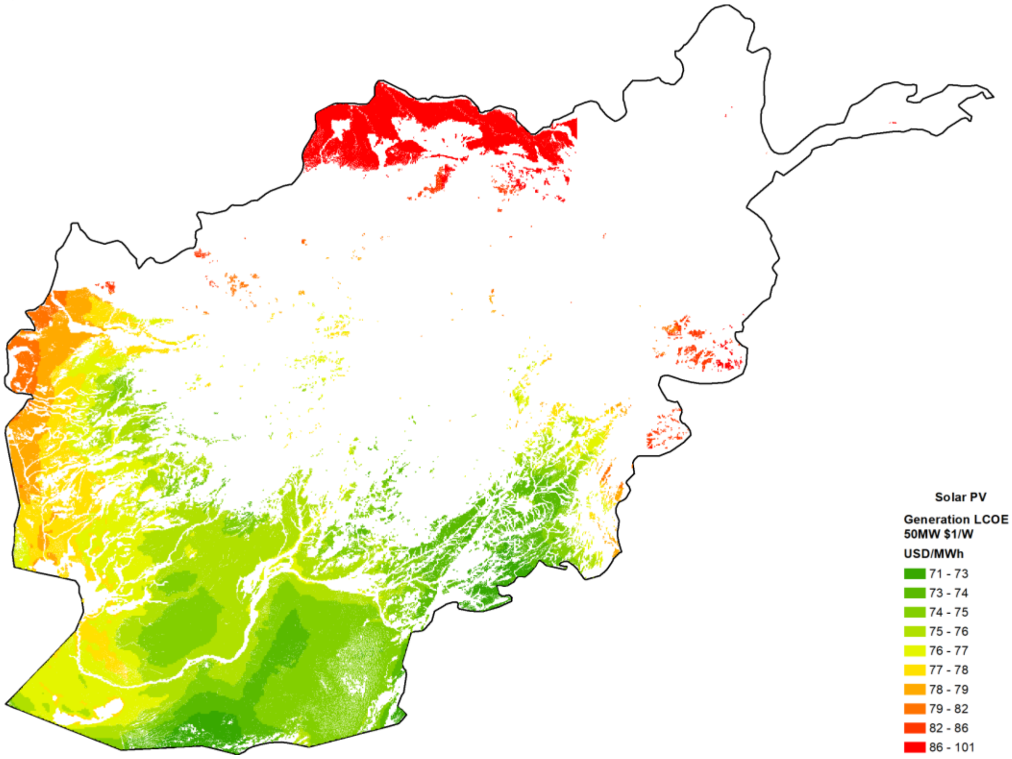
Figure 4.4 Total levelized cost of wind energy (LCOE) – Generation only



The cost estimates shown above for solar PV installations (Figure 4.2) are based on an installed cost of US$1,400 per kW – roughly equal to the 2017 global average for solar PV. Given that the capital costs of solar are expected to continue to drop, a cost analysis was also carried out assuming an installed cost of US$1,000 per kW. The results are shown in Figure 4.5. The LCOE of generation only falls from a minimum of US$0.097 to US$0.071 per kWh and from a maximum of US$0.137 per kWh to US$0.101.

Additional operations can be conducted on the estimated project opportunity areas. Potential sites can be grouped into larger zones. Also, multi criteria decision analysis can be used to assign weights to different factors, calculate scores for potential sites, and rank the sites accordingly. For example, weights can be assigned to the slope of the sites (the smaller the better), and to population density, distance from water source, LCOE, etc. and the sites can be ranked based on the final score, although this type of ranking involves subjective assumptions, and may be less robust than the simple ranking based on LCOE.

Figure 4.5 Total levelized cost of solar PV (LCOE) - Generation only – Low Capital Cost Scenario



4.3 Optimize Scaling of Wind and Solar Resources

A third exercise in integrating renewables into the system expansion plan was carried out by a team of analysts attached to KTH-dESA, a division within the KTH Royal Institute of Technology in Sweden[49]. The objective of the work was to optimize the use of renewable resources, both in terms of technology and market (grid-connected or mini-grid) and test its viability against an exogenously determined cost of conventional grid power. Each technology and scale has a cost attached which in turn is linked to the accessible market, and the availability of the resource. Incorporating this level of detail into the analysis is made possible through the use of detailed geospatial data.

A GIS resource database has been developed which includes high-resolution (1-km) annual wind power maps and high-resolution (10-km) annual and seasonal solar resource maps. These resource data have been incorporated into a Geospatial Toolkit (GsT) which allows the user to examine the resource together with other key information including population, load centers, transmission corridors, generation facilities, terrain and land use, and the like.

[49] KTH-dESA, A GIS Approach to Energy System Planning in Afghanistan, Final Report, February 2017

The dESA team used the GsT together with a least cost optimization model to determine the best mix of RE technologies to meet forecast residential electricity demands throughout the country under various sets of assumptions regarding variables such the annual consumption levels of urban and rural households, the price of imports, and the cost of grid-based energy.[50]

The researchers began with forecasts of total population, divided between urban and rural, and with assumptions as to the number of persons per household to project the total number of urban and rural households in 2030. They then adopted a scenario approach with respect to the average annual consumption of each type of household under different levels or tiers of appliance ownership and consumption. Tier 1, the lowest, assumed that electricity was used only for task lighting and possibly a radio and mobile phone charging. Tier 5 included a full range of electric household appliances, including continuous appliances such as air conditioners. Their base case demand forecast assumed that urban households consumed at the Tier 5 level, while rural households were at Tier 3. Under this scenario, total net residential demand in 2030 would be just over 14,000 GWh. Unlike the APSMP forecasts, these projections assume that 100 percent of households have access to electricity (although not all from the grid). Regional allocations of future population were based on projected future rural and urban populations in each province.

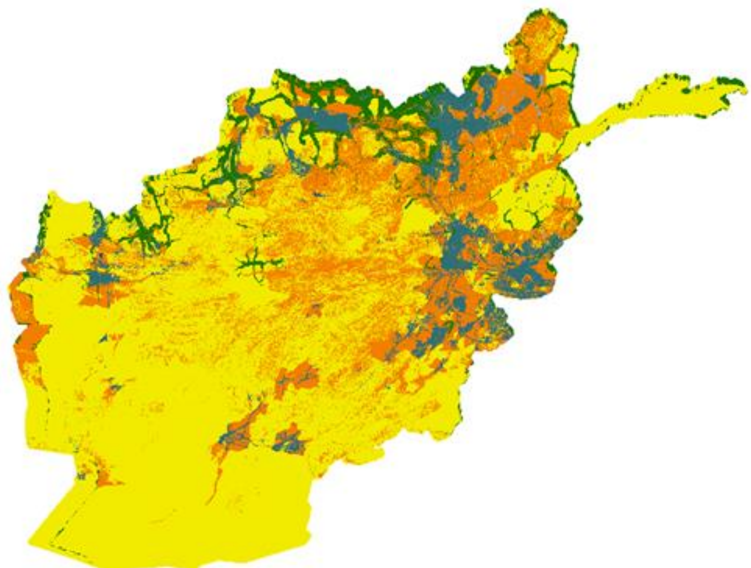
The optimization analysis was carried out using a modifiable least-cost electrification model developed by dESA, known as the **O**pe**N** **S**ource, **S**patial **E**lectrification **T**ool (ONSSET), which estimates, analyzes and visualizes the most cost-effective electrification option for the achievement of electricity access goals. The tool is focused on the assessment and deployment of primarily renewable technologies.[51]

The optimized sets of future renewables-based generation plans prepared in the KTH-dESA study provide interesting findings regarding the best technologies and scales for the integration of renewables into the Afghanistan supply system. For example, at low consumption levels, grid connection was the best option only for settlements close to previously connected villages and transmission lines. Stand-alone systems such as SHS were preferred for more remote settlements. However, mini-grids played little part in the optimal mix. As consumption per household increased to mid-range levels, connection to the grid became attractive to households at increasing distances from the existing transmission lines. High consumption levels further expanded the range at which grid connection was the best option. However, at these consumption levels, mini-grids became more attractive than stand-alone systems for households further removed from the grid. Overall, the model found that off-grid systems were most attractive for between 55 and 73 percent of the population. When the assumed electricity consumption is relatively high (above 1500 kWh per hh per year) however, off-grid technologies might account for between 40 and 50 percent of the people gaining access to electricity.

[50] KTH-dESA, op cit
[51] KTH dESA, op cit, p 5

Figure 4.6 below shows one example of the graphical output from the study work. This case assumes a mid-range level of consumption per household, a high price for diesel, and grid supply cost of US$0.077 per kWh. Blue areas are those where grid connection is optimal, orange areas are mini-grids and yellow areas are stand-alone systems.

Figure 4.6 Optimal Sourcing of Electricity Supply



This technique addresses many of the issues associated with incorporating renewables into traditional generation planning models in that it is able to specify the cost of alternative renewable options for defined geographic sub-regions taking into account the availability of the renewable resource, the size of the market, and the cost of delivery either through the main grid or through distributed generation. It requires some generalizations. For example, consumption per household, while differentiated between urban and rural, is otherwise the same throughout the country, as is the cost per km of new transmission, and the cost of grid supply. Changes in these parameters can be dealt with through scenarios, but an excess of scenarios tends to cloud the decision process.

Another difficulty with the technique is that it is not dynamic. It provides a profile of the optimal set of renewable generation plants at a specified future point in time, but does not provide guidance as to the timing of implementation. This is important for prioritizing projects since sequencing on the basis of lowest unit cost may lead to periodic inefficiencies - for example, if the system is short on capacity but not on energy but the lowest cost plant is capacity constrained. Care is also needed to set the timing and scale of new projects consistent with demand growth. Finally, the model used in the KTH-dESA study did not factor into the unit costs the reliability factor associated with the variability of solar and wind power availability. While this is not likely to be an issue where grid-scale renewables are connected to the grid (unless the only other generation in that segment of the grid has similar issues with availability), it should be a concern in the evaluation of renewables-based mini-grids and stand-alone systems with costs adjusted either to cover the cost of backup or storage or to cover the lost welfare owing to partial as opposed to full supply.

4.4 Next Steps

This chapter has discussed possible approaches to planning for the integration of RE into Afghanistan's electricity supply network. Among the key findings are the following:

- The APSMP optimization models showed a significant role for hydroelectricity in the future profile of electricity supply. However, the APSMP was carried out at a time when the costs of other RE options still reflected the high costs associated with immature technologies, and as such these alternatives did not figure in the Plan. Introducing options such as grid scale wind or solar into the proposed configuration at this stage is complicated by the fact that much of the development anticipated over the intervening 4 years, either in terms of markets or sector investment, has not materialized. Manipulating the Plan without doing a detailed update of inputs could lead to sub-optimal results.

- Preliminary analyses based on GIS data suggests that there are many viable sites within the country for grid-scale solar and wind farms, which would deliver energy at attractive costs. However, further refinement of the findings is needed to take into account other factors such as planned extensions of the transmission network, focal points for demand growth, and cost estimates that reflect the special characteristics of construction in Afghanistan.

- Optimization analysis using the GIS database together with geographic projections of customer demand suggest that a combination of grid-scale, mini-grid and stand-alone systems based on RE technologies could represent a cost-effective plan for future electricity supply. Again, further refinement is needed to upgrade the input data and assumptions to better reflect both future costs and markets.

Both GIS-based studies of the future potential for RE development show strong promise to yield useful findings regarding the optimal role of RE in the future generation expansion program. The GoA and World Bank are currently working together to expand the GIS analysis to identify potential sites for utility scale solar in selected areas of interest. In many instances, however, the available input data is limited or out-of-date and as such the results of the work are suspect. Key initiatives to improve the quality of planning for RE would include:

- Developing realistic and up-to-date estimates of the costs of constructing RE supply sources, both in different locations and at different scales. This includes the cost of constructing the large HPPs that form a part of the APSMP, and the costs of storage or backup supply to offset the variability of RE resources.

- Updating the costs of alternative supply sources including gas and oil-fired diesel, other thermal plants and imports.

- Updating the demand forecast both for households and for commercial and industrial enterprises. The household energy survey ongoing in early 2018 under the Afghanistan Energy Study will provide useful input to the projection of household demands and to the better understanding of how electricity fits into the household energy mix.

5 LEGAL AND REGULATORY ISSUES

As part of its commitment to provide upwards of 10 percent of future electricity demand through RE, Afghanistan has taken a number of steps to establish a suitable legal and regulatory framework. The National Renewable Energy policy and strategies and guidelines for implementation of RE policy represent the core of the proposed framework, but progress has also been made on related fronts that should help to create an enabling environment for the private sector participation – both domestic and international - and create public/private partnerships (PPPs) for generation and service delivery.[52][53] For example, Parliament passed a Private Investment Law in 2005. The rural electrification policy similarly encourages private sector involvement, particularly in areas that are likely to be unserved by the grid, to provide energy to support commercial activity. An Electricity Law, which is expected to be submitted to Parliament in 2017 explicitly allows for private sector involvement in generation and the provision of electricity services. The formation of an independent electricity regulator is underway, as are guidelines for private sector electricity operators.[54] This chapter highlights the key aspects of the legal and framework surrounding development of both the sector as a whole and of RE in particular. It also highlights areas in which the framework requires further work in order to conform with international best practices and discusses ways in which gaps in the framework might hinder the development of RE in the country.

5.1 Existing RE Policies and Strategies

Much progress has been made in recent years by introducing policies that will support the development of RE resources. Table 5.1 below gives an overview of existing documents and laws that are related to investment in the power sector and particularly in RE investments. Detailed summaries of some of the primary policy current documents that govern the overall Afghan RE strategy are provided below: 1) Power Sector Master Plan, 2) Afghanistan Rural RE Strategy, and 3) Afghanistan National RE policy and strategy.

[52] Abdul Razique Samadi, 2013: http://www.carecprogram.org/uploads/events/2013/ESCC-Meeting-KAZ/005_104_209_Afghanistan-Strategies-on-Renewable-Energy.pdf

[53] RE policy goals include establishing: 1) Pricing and tariff structures to recover capital and Operations and Maintenance (O&M) cost as well as return on the investment. 2) Financial incentives: corporate income tax, customs duties, sales tax , among others and 3) Clear rules for Resolution of Disputes.

[54] ADB, 2014: https://www.adb.org/sites/default/files/project-document/151922/47266-001-tar.pdf

Table 5.1 Renewable energy development related documents in Afghanistan.

Document	Year drafted	Notes	Responsible institution(s)	Status as of Jan 2015
Private Investment Law	**2005**	Allows for private investment in power sector.		Adopted
Energy Sector Strategy	2008		MEW and MRRD	Adopted
National Energy Supply Program	2013		MEW	Adopted
National Water and Natural Resources Dev. Program	NA		MEW, MRRD, MAIL, MCN	Adopted
Rural Renewable Energy Policy	2013/ 2014	This Policy is limited to renewable energy and rural electrification through renewable energy off-grid systems to supply energy needs for rural population in Afghanistan.	MEW, MRRD	Drafted/not adopted
Afghanistan National Renewable Energy Policy	2015	Comprehensive and overarching policy document that promises to give a stimulus to the RE sector in the country. Includes guideline for Institutional arrangement led by MEW.	MEW	Adopted
Afghanistan Power Sector Master Plan	2013	The existing official Plan (Afghanistan Power Sector Master Plan [APSMP]) for power system expansion puts a heavy focus on RE, in the form or large-scale hydro, as a source of supply.	MEW	Adopted
Energy Services Law	2015		MEW	Adopted
Afghanistan National Renewable Energy Strategy	2015	Supports and supplements RENP. Mandates strengthening / restructuring MEW's RED, establish ZRECs. Prepare regulatory scheme – e.g. RPO in Electricity Law, prepare standard PPAs.	MEW	Drafted
Afghan National Renewable Energy Action Plan	2015		MEW	Drafted
Renewable Energy Roadmap	2017	ADB report give an overview of different technology options, business models and cost estimates to achieve 5000MW RE by 2032.	MEW	Drafted
Power Services Regulations Law	2015	Establishes Energy Services Regulations Department (Energy Regulator) under MEW. De-licenses and deregulates small scale power production through renewables of upto 100 kW generation plants	MEW	Approved
Feed-in-Tariff Policy	2015	Provides critical comfort levels to the private sector in terms of revenue assurances. Major enabling factor in fast-tracking projects in the RET sector	MEW	
Investment Policy	2015	Significant in terms of facilitating and attracting investment in the Afghan economy – strong links for private participation in the RET sector		Final, Dari
National Integrated Energy Policy	2016	Outlines plan for strengthening energy planning, coordinating institutions/policies.		

Public Private Partnership Law	2016	Provides the policy guidelines for setting up public-private partnerships, with the objectives of regulating PPPs keeping in mind transparency, competition and cost effectiveness; key provisions include formation of a Central Public Private Partnership Authority (CPPPA).	Approved
Afghanistan energy sector 5 year self-sufficiency plan	2016	The plan describes recommended outcomes, outputs, and required tasks for the energy sector	Approved

Sources: WB, 2017. DB RE 2032 Roadmap, 2017, Ershad, 2017

Power Sector Master Plan (2013): The existing official Plan (Afghanistan Power Sector Master Plan [APSMP]) for power system expansion puts a heavy focus on RE, in the form or large-scale hydro, as a source of supply. The Plan also emphasizes extending and integrating the national grid such that future demand growth is increasingly served through grid-based supply. While the Plan makes little mention of, and allocates no budget to distributed generation or the development of individual supply or mini-grids based on renewables, it does, however, note that as costs change over time, other grid based renewables such as large-scale wind and solar may find a place in the generation expansion sequence.

Afghanistan Rural Renewable Energy Policy (ARREP) (2013): ARREP was drafted by MEW and MRRD with the strategic objective of creating better social, economic, and environmental conditions for the rural population of Afghanistan. Specific objectives of the Policy are to increase income generation of households by increasing energy access, provide affordable, clean, and sustainable lighting, heating, and cooking devices, reduce health and environmental impacts of energy use, and improve opportunities for income generation, poverty alleviation, and energy efficiency. This Policy is limited to renewable energy and rural electrification through renewable energy off-grid systems to supply energy needs for rural population in Afghanistan.

Afghanistan National Renewable Energy Policy and Strategy (2015): In line with the plan to meet 10 percent of national demand with RE by 2032 (350 - 450 MW), the GoA has set out an RE policy and policy implementation strategy with a focus on stimulating privately-financed projects, both small-scale and large and is consistent with ARREP and APSMP. The policy provides candidates and financial viability for potential projects. Some of the salient features include:

- Projects up to 200 kW can be implemented under the auspices of the MRRD, and projects of less than 15 kW that are implemented by parties other than the Government will not require licensing.
- Assurances and/or incentives to private sector partners including additional financial incentives, and assurances with respect to power purchase or wheeling, assistance in land acquisition, and procedures for tariff formulation.
- The RE strategy document lays out key action items on issues such as institution building and strengthening, regulatory framework, technical and cost issues, program financing, and integration of gender and environmental objectives.

5.2 Key Stakeholders and Institutional Arrangements

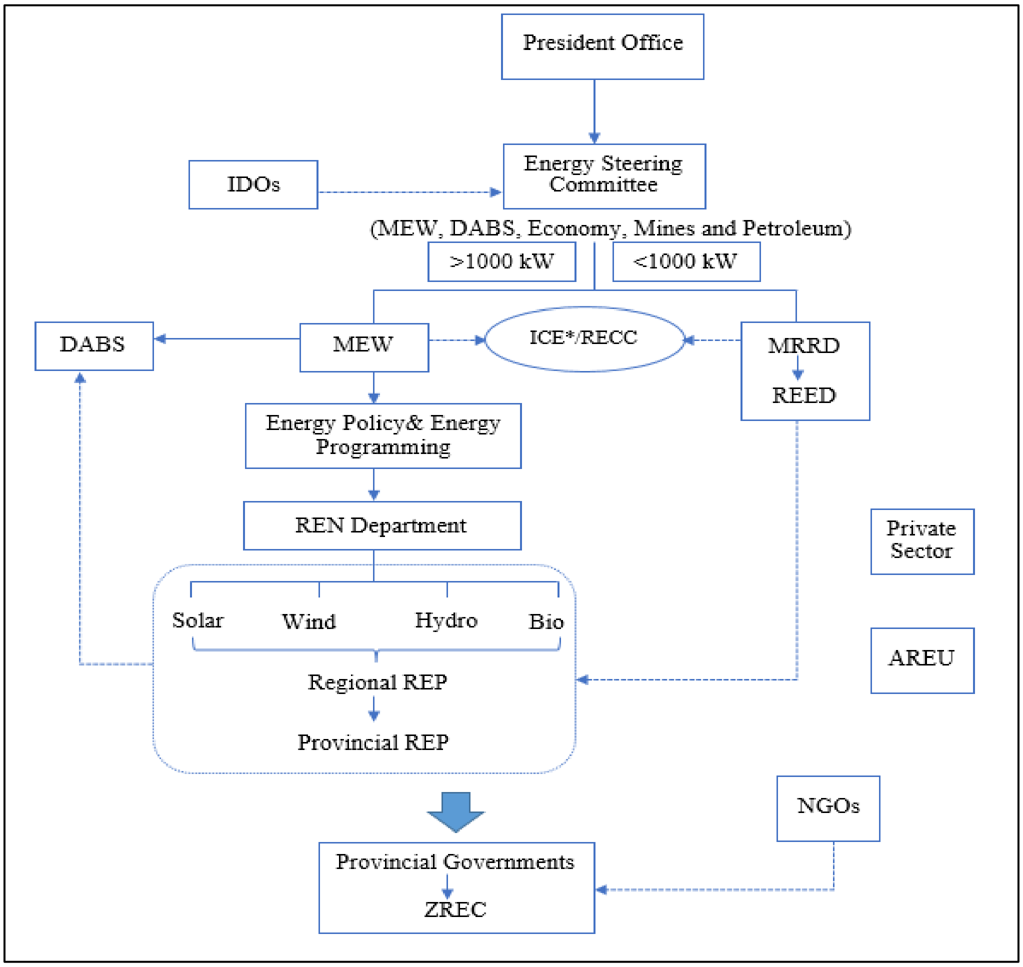
This section provides a brief overview of Afghanistan's RE landscape and the key players involved.

Afghan Government

The role of Government is to provide a policy and regulatory framework that encourages and facilitates participation of the private sector[55] and civil society in electrification. The arrangements and organizations are subject to change pending the implementation of the RE policy where strengthening and restructuring organizations are planned. Figure 5.1 below provides an overview of the existing structure- further details on the organizations are provided in the section.

[55] Private sector as Independent Power Producers (IPP), communities and local entrepreneur will be encouraged to develop and manage RE projects on Built-Own-Operate (BOO) basis, and will be governed by appropriate regulations.

Figure 5.1 Afghanistan RE Sector Institutional Arrangement



Source: WB, 2017

The ***Energy Steering Committee (ESC)*** under the President's Office is the highest decision-making body in the energy sector of Afghanistan. The committee reports directly to the President's Office and is currently chaired by President's Senior Advisor on Technology and Infrastructure. Other members are Ministers of Energy and Water, Economy, Mines and Petroleum, and Finance and CEO of DABS.

The two ministries responsible for RE development in Afghanistan are ***MEW (Ministry of Energy and Water) and MRRD (Ministry of Rural Rehabilitation and Development).*** Overall, renewable energy promotion for commercial and urban application is mainly the responsibility of Renewable Energy Department (RED) of MEW. Rural renewable energy and rural electrification promotion for projects up to 1000kw is directed by the MRRD Rural Energy and Enterprise Directorate. In case MRRD is implementing projects above 1000 kW capacity, it will coordinate with MEW, and likewise MEW will coordinate with MRRD when implementing projects below 1000 kW in the rural area. Projects below 100 kW are delicensed. DABs is the state owned utility responsible for the operation and management of the power systems.

Inter-ministerial Commission for Energy (ICE) [56] ***and Renewable Energy Coordination Committee (RECC):*** In an effort to improve coordination between the two ministries, ICE and RECC were created as is a joint initiative by MEW and MRRD. RECC included its technical working groups (TWG) for promotion of different technologies such as solar, wind etc. The Zonal Renewable Energy Committees (ZRECs) oversee project implementation at the providential level, and coordinate with the RED.

Non-Government Stakeholders

Afghanistan Renewable Energy Union (AREU): Formed in 2013 under the Afghanistan Chamber of Commerce and Industries, AREU is a non-profit industry association of 45 domestic renewable energy companies - consisting of equipment manufacturers and system integrators. AREU regulates RE products and services to facilitate RE standardization. It also assists the international investors and stakeholders in the appropriate investments guiding them using the national RE trade policies and procedures.

International Development Organizations**:** GIZ, ADB, USAID, WB and other IDOs play important roles in RE project financing and TA to the government. GIZ have been very active in terms of technical assistance and financing of RE projects. USAID has been heavily involved in off-grid rural energy initiatives – such as micro-hydro projects under the NSP. ADB and WB have been helping to lead the policy level work, including the RE roadmaps.

NGOs: The RE strategy recognizes the catalytic role that NGOs play in implementation of rural community oriented and community focused RE projects, it would be important to put a formal coordination mechanism in place to ensure exchange of information and ideas on one hand, and to avoid overlaps of efforts on the other. As defined by the in ANREP, such a mechanism would be institutionalized in TERM 1 (2015-2020) which would also include incentives, facilitation and felicitation of NGO led efforts. This mechanism will be upgraded to a registration approval platform in TERM 2 (2021-2032).[57]

5.3 Key Gaps in RE Sector Governance

The current governance situation is mixed. There is strong government commitment towards RE deployment, but the incomplete RE strategy and crowded institutional arrangements need to be addressed.

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[56] Although ICE was closed in 2012, RECC continued to receive funding. RECC is chaired by both Deputy Ministers of MEW and MRRD. Currently, RECC has one staff assigned by GIZ to manage the meeting.

[57] Term 1 in the ANREP (2015-2020) focuses on creating the enabling conditions for private sector involvement and adding an additional 50 MW of RE generating capacity. Term 2 of the Policy (2021-2032) envisages the addition of 100 MW of RE generating capacity by the private sector.

Table 5.2 Current Afghanistan RE Sector Strengths and Gaps

Strengths	Gaps
Separation of policy and operations (MEW vs DABS) Formally adopted policies for Renewable Energy Good data sets on current production and consumption by province	Too many agencies involved (MEW,RED,DABS,MRRD, various coordinating committees at national and sector level) and lack of coordination between authorities, resulting in long lead times and delays Low institutional capacity RE implementation strategy not fully developed

In Afghanistan, the strengths of the RE governance lie in the separation of policy and operations with MEW and DABS. The country has also made admirable progress in formally adopting RE policies as covered in previous sections. However, RE implementation strategy is not fully developed and some key issues will need to be addressed if it is to achieve its RE aspirations:

Lack of coordination between the multiple RE agencies involved. The county has no clear guidance on who is leading RE expansion country. There are two major ministries as (MEW, MRRD), as well the state utility (DABS), in addition to the various sub-departments (RED) and coordinating committees at national, provincial and sector level. Ministries such as the Ministry of Finance, Ministry of Economy and Ministry of Mines and Petroleum are also involved in planning and budgeting electrification projects. In addition to the five ministries, there are ten or so development agencies, private sector partners and civil society organizations also active in the sector. The result of this is perfectly illustrated in the three separate RE policy strategies produced – 1) APSMP – relevant for DABS/MEW, 2) ARREP for MRRP and 3) ANREP by MEW. The delineation of roles and responsibility and the lack of coordination between authorities has resulted in long lead times and delays.

This ad-hoc approach also spills into lack of donor coordination, which has resulted in concurrent, sometimes overlapping work being done with supporting development partners. The uncertainty also impacts potential investors since there is no clear one-stop shop for RE development. All these factors make RE investments more expensive than they might otherwise be. The situation is exacerbated by the security and political situation, as well as the decentralized nature of governance in the country. A financing institution could help address barriers of higher initial investment costs through loans, grants, and tax reductions. Indeed, the prevalent governance issues in Afghanistan such as legislative and public administration issues, political patronage, corruption and lack of presence in rural areas have contributed to inefficiencies and dissatisfaction with local governance. Efforts to strengthen local governance and service delivery will no doubt help to also improve RE governance.[58][59]

[58] http://www.nispa.org/files/conferences/2013/papers/201304161044150.Paper_Habib.pdf?fs_papersPage=8
[59] http://www.refworld.org/pdfid/533165784.pdf

The low institutional capacity of the key implementing agencies will require additional technical support. MEW and MRRD – in their present structures – received updated mandates, policies and strategies after the establishment of the new Afghan Republic in 2002. The respective RE departments were created more recently, while DABs was only incorporated in 2008. As a result, much of the institutional capacity is still being developed and the current organizations have not yet matured into institutions capable of efficiently and effectively overseeing the RE sector. Knowledge gaps will also need to be addressed, including Afghan specific costing estimates for different technologies, and demand side data on household energy usage, especially for rural areas. These information gaps will need to be addressed for an accurate assessment of the best technology mix (RE/Non-Re, On-grid/Off-grid) for the various parts of the country. The capacity building and knowledge generation initiatives will require significant partnership with development organizations.

Many details of the policy framework have yet to be defined. While a National RE Strategy and RE Action Plan have been drafted by MEW, they have not yet been formally adopted. Since these set out the roles and responsibilities of the various parties and the steps to be taken to implement the NREP, it is important that their recommendations be formalized. In addition, many accompanying regulations and laws will need to be passed to ensure effective implementation of the NREP. Issues such as the nature and structure of the regulatory authority, tariff setting mechanisms, and the rights and obligations of the GoA and DABS with respect to private sector developers all need to be defined and codified.

5.4 Review and Analysis of RE institutions and policies

In order to clarify the extent to which Afghanistan's current RE related institutions and policy framework include basic features considered necessary for a successful RE development program, a comparison was carried out between the Afghan institutions and those of other countries in the region. The country's current status was also assessed against benchmarks established by IRENA (International Renewable Energy Agency), REN21 (Renewable Energy Policy Network for the 21st Century) Global Status Report and the WB RISE (Regulatory Indicators for Sustainable Energy) indicators. This section summarizes the key findings.

5.4.1 Comparison of RE institutions with those of other SAARC Countries

Comparing the institutions to other South Asia Association for Regional Cooperation (SAARC) nations and best practices in the literature review, it becomes clear that there are a few gaps that Afghanistan will need to address. 1) First is the absence of an independent regulator – which exists in all the SAARC countries except Nepal, Bhutan and Maldives. 2) The financing sector in Afghanistan is still in its infancy, and establishing a financing institute is something that should be a priority since traditional private financing may be hesitant to invest in potential RE projects due to the high risk and security issues. IDCOL and IREDA and have been quite prominent in energy infrastructure financing in Bangladesh and India. 3) India, which has done incredibly well in scaling up RE capacity over the last decade also is the only country to have a separate full-fledged ministry for RE – and not just a department under the energy ministry. Nepal has the Alternative Energy Promotion Center (AEPC), which is a government institution under the Ministry of Population and Environment – but its scope has been limited to rural energy needs such as off-grid SHS, micro-hydros and cook stoves.[60]

Table 5.3 Comparison of South Asia RE Institutions

Country	Ministry	Federal Institute	Regulator	Financing Institute
Afghanistan	Ministry of Energy and Water, Ministry of Rural Rehabilitation and Development	Renewable Energy Department	Ministry of Energy and Water – (Energy Services Regulation Department)	None
Bangladesh	Ministry of Power, Energy and Mineral Resources	Sustainable and Renewable Energy Development Authority	Bangladesh Electricity Regulatory Commission	Infrastructure Development Company Limited
Bhutan	Ministry of Economic Affairs	Department of Renewable Energy	Bhutan Electricity Authority	None
India	Ministry of New and Renewable Energy	Energy Efficiency and Renewable Energy Management Center	Central Electricity Regulatory Commission, State Electricity Regulatory Commissions	India Renewable Energy Development Agency Ltd, Rural Electricity Corporation Ltd.
Maldives	Ministry of Environment and Energy	State Electricity Company Ltd.	Maldives Energy Authority	None
Nepal	Ministry of Energy	Alternative Energy Promotion Center	Nepal Electricity Authority	None
Pakistan	Ministry of Water, Ministry of Power and Energy	Alternative Energy Development Board	National Power Regulatory Authority	None
Sri-Lanka	Ministry of Power and Energy	Sri-Lanka Sustainable Energy Authority	Public Utilities Commission of Sri-Lanka	None

Source: WB, 2017. SAARC Energy Center, 2015:
http://www.saarcenergy.org/wp-content/uploads/2016/06/Study%20Report.pdf

5.4.2 Ranking in International RE Benchmarks

This section analyzes three international RE policy benchmarks - 1) IRENA Key Policy Factors, 2) REN21 Ranking, and 3) WB RISE Indicators - to compare Afghanistan to other neighboring countries. However, it must be noted that these benchmarks do not consider policy effectiveness or compliance. This analysis provides some insights onto how Afghanistan currently fares relative to its neighbors. Overall, a direct comparison is difficult since Afghanistan is still developing a legal/regulatory framework for implementing its RE policies and many of the details are still being

[60] AEPC Website: http://www.aepc.gov.np/index.php

worked out. Nevertheless, the analysis of the three benchmarks reveals there is a solid policy backbone in place for RE development.

In all three benchmarks, Afghanistan scores quite high in terms of having conducive policies with provisions in the RE policies aligning quite favorably in terms of key factors outlined in the three benchmarks. For example, land acquisition is a major concern that has been discussed ANREP. Afghanistan already has a RE target, provides tax exemptions, working on preferential tariffs and has a renewable portfolio obligation (RPO) all specified. However, it remains to be seen how MEW and DABS will implement these policies in terms of an effective legal/regulatory framework, such as for adopting a FIT policy and enforcing RPO. Afghanistan also lacks some key policies detailing governance for specific resources/policies, for example, Nepal has a Hydro-Power policy, and India has specific Solar/Wind policies with specific provisions for environmental and social concerns.[61]

IRENA Key Policy Factors: Overall, Afghanistan's 2015 National RE Policy (ANREP) and Rural Renewable Energy Policy (ARREP) align well with the requisites outlined by IRENA, and include considerations for social inclusion/equity/gender issues. The policy is not very specific and lacks details on issues such as tariff setting and subsidies i.e. will tariff for different renewable energy sources be determined separately? Nevertheless, both ANREP and ARREP cover a wide range of issues. They emphasize provisions for many different financial and non-financial incentives to attract RE investors – such as income and sales/customs duty tax exemptions, and support for facilitating land acquisition and security during project implementation. AREU is already involved in aspects related to adoption of standards and quality control for equipment. Social sustainability/inclusion aspects are also considered, with projects benefitting women and children being eligible for the highest share of subsidies. However, there is no specific mention of requiring benefit sharing mechanisms.

[61] MNRE, 2013: http://mnre.gov.in/file-manager/UserFiles/report-on-developmental-impacts-of-RE.pdf

Table 5.4 IRENA key policy factors: ANREP and RREP

IRENA Key Policy Factors	ANREP	Rural REP
RE Targets set by governing body	Yes - 10 percent of national demand with RE by 2032 (350 - 450 MW).	N/A
Selling Tariff of electricity from RE sources (Feed-in Tariff)	No FIT. RPO required for industrial and commercial consumers of electricity in TERM 2.	Yes – provision for Power purchase agreements between independent power producers.
Incentives for developers to implement RE power generation (Non-Financial incentives)	Support for: Facilitate Land acquisition Security during project implementation. Wheeling and Banking allowed through grid Must-Run Status for all RE evacuation	N/A
Financing Support for RE project developers (Financial Incentives)	Subsidies could be given in the form of Preferential Tariffs, Performance Linked Incentives or Viability Gap Funding.	N/A
Permit and Licensing Structure for RE power generation	Licensing required for projects >15KW. RE projects allowed for both captive and third-party sale of electricity.	N/A
Other technical aspects such as grid codes for RE power connection	Adoption of standards, performance benchmarks and quality control for equipment.	Development of a Grid Code for micro hydro plants to grids.
Social Inclusion/gender Considerations	Promotes stand-alone projects providing basic energy services to remote communities, projects supported by/benefiting women and children may receive highest allocation of subsidies.	Primary Strategy is to improve social, economic and environmental conditions.
Implementation Capacity Considerations	Existing Institutions may be reorganized/new institutions Capacity enhancement program at institutional level and for stakeholders planned	N/A
Other	Integrate RE with energy efficiency practices Prioritizes smaller scale towards areas unlikely to have grid access. Support for local manufacturing, assembly, repair & maintenance	N/A

Source: ANREP, RREP

RISE and REN21 Comparison of RE indicators: The WB RISE indicators (Regulatory Indicators for Sustainable Energy) gave Afghanistan the lowest score in comparison to other regional and neighboring countries – with an overall score of 27. However, on closer inspection, the low score is slightly deceptive as it primarily due to not having a legal framework for RE (Indicator 1.1) and the lack of financial and regulatory incentives (Indicator 3 and 4). Indeed, Afghanistan gets a quite high score for planning and RE expansion (Indicator 2) coming in second only to China with a score of 68. Once the RE roadmap is finalized and the policies implemented, Afghanistan can dramatically improve its score and position in overall rankings.

Table 5.5 RISE Indicators for Afghanistan and Neighbors

RISE Indicators	Afghanistan	Pakistan	India	China	Bangladesh	Nepal	Sri Lanka	Maldives	Iran	Tajikistan	Uzbekistan
Overall Score	**27**	77	67	74	57	45	62	36	59	36	30
Indicator 1: Legal framework for renewable energy	**50**	100	100	100	100	100	100	50	100	100	100
Indicator 2: Planning for renewable energy expansion	**68**	59	68	36	51	43	85	63	39	38	31
Indicator 3: Incentives and regulatory support for renewable energy	**0**	100	75	63	75	75	75	100	100	38	38
Indicator 4: Attributes of financial and regulatory incentives	**0**	100	100	78	56	67	83	33	67	67	33
Indicator 5: Network connection and pricing	**61**	100	67	89	33	11	58	0	58	0	0
Indicator 6: Counterparty risk	**10**	80	57	100	85	22	32	3	49	12	8
Indicator 7: Carbon pricing and monitoring	**0**	0	0	54	0	0	0	0	0	0	0

Source: WB RISE 2016

The REN21 2016 Renewables Global Status Report- which overviews global and country progress for RE implementation- does not rank Afghanistan. However, in comparing between the regulatory policies, public financing and fiscal incentives, it is clear how much advanced China and India are in terms of establishing the required framework compared to other countries in the region. For example, India has a net-metering policy at the state level[62] and both countries have Renewable Portfolio Standards (RPS).[63] Both countries are global RE leaders primed with large scale investments to further boost their RE capacity. The experiences of these countries provide a useful guide in laying out the RE Roadmap and reform requirements.

5.5 Lessons Learned from International Experience

The literature on good RE governance, as exemplified by experiences in different countries also provides useful guidance on areas on which Afghanistan should focus as it further develops its RE policies and institutions.

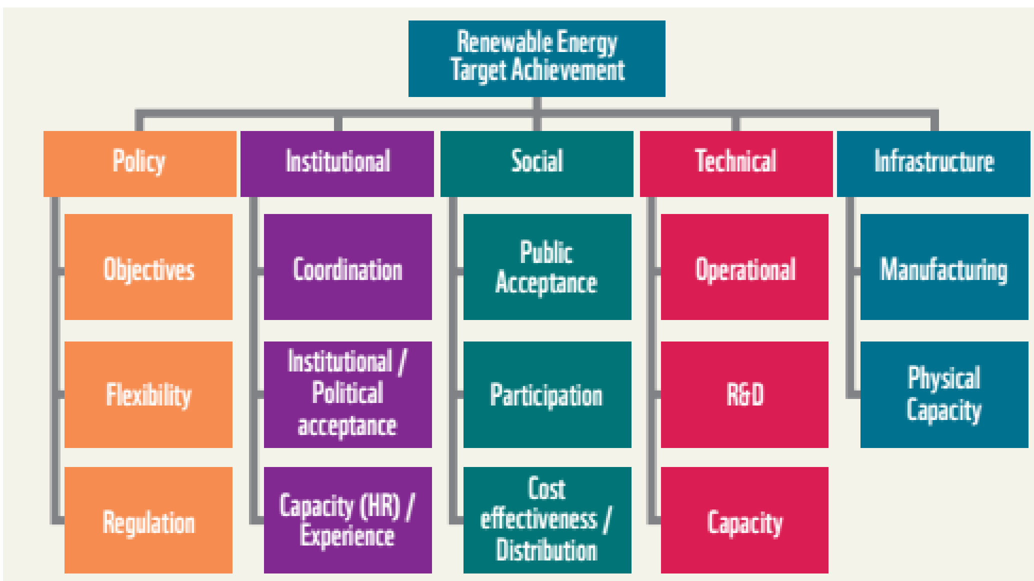
According to REN21[64], setting achievable renewable energy targets together with feed-in tariffs have had the biggest impact on renewable energy deployment. Feed-in policies now exist on every continent, and targets are highly visible ways to demonstrate commitment to renewable energy. Since 2004, the number of countries promoting renewable energy with direct

[62] Net Metering Initiatives in India: http://www.intersolar.in/en/news-press/news/industry-news/net-metering-initiatives-in-india.html
[63] RPS obligates generators, suppliers and consumers to meet a certain % of their energy to come from RE sources.
[64] REN21, 2014: http://www.ren21.net/Portals/0/documents/activities/Topical%20Reports/REN21_10yr.pdf

policy support has nearly tripled, from 48 to over 140, and an ever-increasing number of developing and emerging countries are setting renewable energy targets and enacting support policies. Policy targets have become increasingly ambitious, and their focus is expanding beyond electricity to include heating, cooling, and transport. In parallel, policy mechanisms have continued to evolve. These include the use of policy instruments differentiated by technology, as well as the evolution of feed-in policies for premium payments and for use in the heating sector.

Policy, planning and regulations are key to achieving RE targets but require an enabling environment. Announcing targets and enacting policies is not sufficient to ensure the announced targets are achieved. Case study analysis done by the World Resources Institute (WRI)[65] suggests that the effectiveness of any policy intervention depends on the coordination of several key factors including policy, institutional, social, technical and infrastructure (Figure 5.2), although policy and institutional factors were found to be the most relevant key factors.

Figure 5.2 Key Factors in Achieving RE Targets



Good governance principles often result in more effective and informed policy outputs and greater social acceptance. In Afghanistan, social acceptance/buy-in will play a crucial role. With clear community benefits through efforts such as benefit sharing, the risk of project opposition is minimized – this is especially important in terms of the precarious security context in Afghanistan. The lack of strong private and financing sectors are major challenges. However, since the RE sector in Afghanistan is still very young, it also gives the opportunity to bypass potential issues faced by other countries such as the power sector/market acceptance of RE by utilities, and grid integration/variability issues in the future.

[65] WWF&WRI, 2013: http://awsassets.panda.org/downloads/meeting_renewable_energy_targets__low_res_.pdf

An ongoing and inclusive multi-stakeholder consultative process during RE planning and implementation is key. This will not only result in social and political acceptance, but also improve coordination and cooperation among relevant decision makers. The RE policy consultation process should start at the beginning of the planning process, involving investors, producers, distributors and technology providers. These consultations help build confidence and cooperation among various stakeholders and offer insights into the range and types of support mechanisms that are needed to make the whole supply chain economically viable.

An independent energy regulator backed by a clear mandate and legal framework is essential. A conducive institutional environment and legal authority will help build on the confidence of private sector investors and ensure compliance with various demand-pull and supply-push instruments - such as fiscal incentives and public financing.

Greater coordination and standardization across implementing agencies, and minimization of bureaucracy and administrative barriers, can have a very positive effect on RE uptake. For example, one of the major reasons for the rapid growth of Germany's SHS was the streamlined procedures and negligible interconnections and inspection costs. On the other hand, unclear guidelines can result in coordination issues that can hinder RE uptake. For example, in Spain, a lack of coordination between regional and national level governments led to poor control of the permitting process leading to a temporary suspension of the solar program (BOX).

Having an overarching RE institution – such as separate ministries or specialized departments - may be inadequate if not provided with a regulatory mandate to oversee the sector development. In India, MNRE's pro-activeness in JNNSM and REC programs concerning misconduct, fraudulent behavior and project execution demonstrate the benefits that a proactive renewable energy agency can bring. In Rajasthan, investigations by the MNRE led to penalties for three companies who received false certificates and 11 others that missed their deadlines[66].

BOX: Spain's Solar Rush

A lack of coordination between the national authority and the 17 distinct autonomous communities has led to serious problems in terms of renewable energy project development and investment security in the country. By 2008, Spain had overachieved its 2010 target by over 2000MW. Too many projects were being approved by the local autonomous governments, whose administrative approval system has been burdened by lack of coordination.

In Spain, renewable energy projects need to go through two separate approval processes: 1) An administrative authorization, which is given at the regional level, and 2) Access to the premium licenses, which if given by the Ministry of Industry, Energy and Tourism at the national level. A lack of governmental and administrative control and coordination has been related to the solar rush that has partially led to the temporary suspension of Spain's Regimen Especial. As of 2012, about 9,000MW worth of renewable energy projects that have received administrative authorization but no national premium licenses.

Source: WWF&WRI, 2013: http://awsassets.panda.org/downloads/meeting_renewabl

[66] http://awsassets.panda.org/downloads/meeting_renewable_energy_targets__low_res_.pdf

In Morocco, the cumbersome administrative process has proven to be a big disincentive for investors, despite the full backing of the King driving the national RE strategy. In 2010, ADEREE was restructured into a legalized national entity to implement the national renewable energy plan. Other institutions such as MASEN (Morocco Agence for Solar Energy), SIE (The Society for Energy Investments) and IRESEN (Institute Research Solar Energy and Energies Nouvelles) were also created. Despite this, with no clear regulatory body in place or operating practices clarified, extra responsibility was put on the developers and private investors, who also had to operate as facilitators, regulators and managers of public services. In 2012, Team Energy Maroc was established by the energy ministry in an effort to coordinate the various institutional roles.

A one-stop shop can help to oversee sector development and streamline processes related to applications, permits and licensing, and determining transmission and distribution requirements. As the European experience has shown, Germany's rapid growth in Solar PV projects is directly attributed to initially establishing a one-stop-shop approach and the very short wait time for permits. This arrangement would be very helpful in countries like Morocco and the Philippines, where the complicated administrative procedures and lack of coordination among permitting agencies has proven to be a disincentive for project developer**s.** For example, the Market Service Center (MSC) was set up in the Philippines as a one-stop shop for renewable energy to remove barriers to renewable energy development but has ceased to exist. The DOE REMB has integrated several functions of the MSC, including managing funds dedicated to renewable energy. This was a step back from the previous arrangement.

However, having provisions for a one-stop shop does not guarantee expedited RE development. In India, states' nodal agencies are supposed to facilitate different clearances required for renewable energy projects, acting as single window clearance agencies facilitating the approvals from different departments. However, the practice in most states is that the burden is on developers to get the clearances required for their projects. This was confirmed by the state nodal agencies of Haryana and Karnataka during stakeholder interviews.[67] As per industry estimates, on an average it takes around a year to complete the land acquisition process in the state. As per Karnataka state policy, the private developers cannot acquire agricultural land for renewable energy projects. The land must be converted to non-agriculture land to be acquired. The whole process of identifying suitable land, conversion, and finally acquisition is an extremely time-consuming process.

The lack of institutional capacity can be a major factor in hindering RE development. For example, South Africa's Renewable Energy Independent Power Producer Procurement Programme (REIPPP), was been unable to stay on schedule for all 3 bidding rounds. This resulted in delays of over 8 months for DOE officials to catch up, as well as to assist bidders struggling to finalize outstanding bid commitments. Nervous investors seriously considered withdrawing their bids due to these prolonged delays.

[67] TERI, 2014: http://www.teriin.org/projects/nfa/pdf/working-paper-14-Governance-of-renewable-energy-in-India-Issues-challenges.pdf

Countries like India and Morocco have recognized low human/institutional capacity as a major bottleneck, and have partnered with organizations to ramp up both short-term and long-term efforts to address this issue. India's MNRE has set up research centers to help achieve renewable energy goals, develop educational and training materials, organize workshops and seminars, and coordinating research and technology development. These centers include the Solar Energy Centre (SEC), the Centre for Wind Energy Technology (C-WET), and the National Institute for Renewable Energy (NIRE). Morocco has taken on training exercises for experts and managers to develop the legal framework and regional strategy, and to establish a network for training and applied research for the renewable energy sector. These initiatives helped to address 1) the dependence of local authorities on centralized funds that are often not allocated regionally; 2) the lack of know-how and legal expertise necessary to promote renewable energy development; and 3) lack of consideration for the potential of renewable energy amongst regional level authorities.

5.6 Recommendations

Afghanistan has already laid a strong foundation for developing its RE sector, and ensuring sound RE governance principles will be crucial to achieving achieve the RE roadmap the county has laid out. Based on the analysis of existing gaps in the Afghan RE sector governance, below are a few crucial recommendations for the way forward:

- **Inclusive consultations with all stakeholders is important to making the RE policies a reality.** Having a rigorous bottom up consultation process at the beginning of the planning process - involving investors, producers, distributors and technology providers - will help build confidence and cooperation among various stakeholders and offer insights into the range and types of support mechanisms that are needed to make the whole supply chain economically viable. The ad-hoc nature of RE planning in Afghanistan has made it difficult to pursue this inclusive agenda and systematically incorporate the views of all the stakeholders.

- **Clearly define roles and responsibilities of RE institutions.** Quite simply there are too many agencies and departments at the ministerial, regional and provincial level with no clear single entity leading the charge. More work needs to be done to improve coordination, and access and address potential administrative/bureaucratic barriers in RE- this effort will no doubt also benefit ongoing Afghan efforts to strengthen local governance and service delivery. While establishing a power sector regulator already underway, it will be important to ensure that it has the independence, legal authority and enforcement capacity to not only fulfill its power sector regulation duties, but also push the RE growth though technology specific policies and strategies. Establishing a one-stop shop will also be a positive signal to help attract potential investors. The country may also want to explore establishing a ministry of RE and an infrastructure financing institution – which would support investments in RE as well as other infrastructures. According to ANREP, dedicated institution shall be established during the period of 2021–2032 – which is a wide range. It would be beneficial to push up the timetable to an earlier period. However, these options will need to be carefully weighed in terms of their benefits versus potentially expanding bureaucracy with more overlapping RE institutions. This is where outlining clear responsibilities and roles will be important.

- **Continue working on improving institutional capacity and reducing knowledge gaps.** Steps should be taken to ensure that planning decisions will be based on sound data and executed by capable staff on the ground. There are already initiatives to improve capacity of government staff and other stakeholders. For example, ADB is developing capacity-building and training programs for the MEW and representatives of regional governments and agencies, covering technical and institutional management in the areas of procurement; financial management; community development; and climate, environmental, and social safeguards. Regular training sessions that extends not just to the ministry level staff, but all the way to the local staff as well, will be essential. To ensure that RE planning decisions are made with the most accurate data possible, more work will need to be done to calculate Afghan specific costing estimates for different technologies, as well as household usage. WB is already working on updating the power systems geospatial data, as well as costing data based on the latest global estimates. Organizations such as The National Renewable Energy Research and Development Center should be deeply involved in the capacity building and knowledge initiatives.

These recommendations may seem straightforward but following them can be challenging in the context of Afghanistan. Nevertheless, with strong commitment from the government and early involvement of development organizations the country has an opportunity to shape the institutions and policies in accordance with international lessons learned and best practices – which will hopefully serve to address or even bypass potential governance issues.

6 RISKS AND BARRIERS TO RENEWABLE DEVELOPMENT

The previous Chapters have discussed Afghanistan's technical potential for various types of renewable energy generation, and ways in which RE can be incorporated into the overall generation profile of the country. They have also described the legal and regulatory environment surrounding RE development in the country, and provided guidance on international best practices to follow as this framework evolves. However, while there are many positive factors, there are also some significant barriers to realizing the full potential of RE, both in the short and in the long term, which need to be addressed in defining the path for development. Barriers to development can be broadly divided into five categories, although there are many linkages among them:

- Security and political risks,
- Technical barriers
- Commercial risks
- Financing barriers.
- Gaps in the legal and regulatory framework

These risks and barriers are of particular concern to the private sector as it investigates the potential to be part of RE development in Afghanistan. The Afghanistan Energy Sector Strategy found lack of overall safety for private sector stakeholders, absence of a controlling setting, and credit value of a possible customer, as prevailing constraints facing greater private sector involvement.[68] However, the risks and barriers can also affect the ability of national institutions such as the energy ministries and DABS to advance the implementation of RE based generation projects.

6.1 Security and Political Risks

The security situation has been a longstanding risk, but appears to be worsening. Whereas the Northern provinces had counted as relatively safe before, Taliban-linked insurgency has now elevated the risk to a country-wide level. In southern Afghanistan, where parts of the country are controlled by the Taliban, the security risk continues to be very high. The spread of insurgents linked to the Taliban, al-Qaeda, ISIS and aligned militia into the northern provinces further limits the areas in which both public and private agencies can formulate and implement development projects. Without addressing security issues, especially in remote areas, it would be difficult for planners and/or developers to collect and verify project data, and to build and operate power plants. At the new height of risk assessed, investments critically will depend on the government's ability to manage these security and political risks, and to convince developers and financing agencies that they can do so.

[68] Raheleh Rostami et al., 2016: http://www.sciencedirect.com/science/article/pii/S1364032116309261

6.2 Technical Barriers

***Limited capacity of the grid to accommodate renewable energy**:* The existing grid is fragmented into smaller sub-grids and in many cases has limited capacity to accommodate addition of large solar or wind plants. Large parts of central and southwest Afghanistan are not served by any grid system at all. Assessment of the grid integration capacity as well as the plant's maximum amount of renewable generation capacity is required for each plant and location being considered. The requirement to conduct extended site-specific assessments to determine these capacities presents a substantial cost and risk (uncertainty). Furthermore, no grid code exists to provide the guidelines needed for designing the grid connection and providing the operating rules for the power plant.

***Lack of electricity demand data to identify locations for mini-grid or stand-alone systems**:* In provinces which are unlikely to be served by the power grid in the near-term (e.g. Ghor, Farah, Bamyan, Daykundi, Nooristan etc.) the Ministry of Energy and Water (MEW) has identified off-grid and mini-grid projects. Already, there are decentralized local grids and stand-alone systems such as solar PV and diesel generators providing electricity in the northern provinces (e.g. mini hydro in Badakhshan and Takhar), but a central, country-wide database identifying electricity demand data and locations for such off-grid/mini-grid solutions is still missing. Rural electrification programs operating in Afghanistan are therefore still in their infancy as they lack comprehensive demand data which is both costly and cumbersome to develop.

6.3 Commercial Risks

Off-taker Risks: The creditworthiness of the off-taker is one of the greatest concerns for investors looking to emerging markets. Especially when the price of power in the PPA is projected to be higher than the average power retail tariff, any investor will insist on credit enhancements or guarantee from the government and/or multilateral agencies to backstop the off-taker's payment obligations.

As highlighted by a sector assessment in 2015, average electricity tariffs of 8–12 cents per kWh were not sufficient to cover imported-power generation costs of 6–10 cents per kWh and Afghan transmission-and-distribution grid costs of 7–10 cents per kWh.[69] In the case of Afghanistan's first IPP, the Mazar 50 MW thermal project, the government had requested an International Development Agency (IDA) guarantee to the amount of US$30 million to backstop its sovereign guarantee for DABS' payment obligations. Despite DABS' achievements in improving its operations and management capacities, the challenge to establish creditworthiness remains as DABS continues to receive donor support.[70]

[69] ADB (2015), *RRP Sector Assessment (Summary): Energy*, https://www.adb.org/sites/default/files/linked-documents/47282-001-ssa.pdf
[70] Through the USAID Power Transmission Expansion and Connectivity (PTEC) Program

While the provision of guarantees can mitigate the perceived high risk, a long term goal should be financial viability of the sector and sustainability of the tariffs. For mini-grid and stand-alone energy systems, which can be privately owned and operated, off-taker credibility also presents a hurdle as reliable payment mechanisms such as mobile pay are only in the pilot-phase, and potential customers to be served in rural Afghanistan do not have a formal credit history.

Currency risks: For any investor/developer, currency risk plays an essential role as many of the incurred costs for debt and capital for equipment are usually made in hard currency (e.g. US$ or Euro), while revenue is collected in local currencies. Local currency devaluation not only decreases the value of payments and thus the value of PPAs, but also increases costs for equipment purchases (modules, inverters, other components are usually purchased in hard currency).

The Afghan Central Bank, Da Afghanistan Bank (DAB), maintains a managed floating exchange rate (i.e. a rate which can be subject to direct or indirect intervention by monetary authorities without a specific path or target), to stabilize exchange rate volatility and respond to such depreciation. Without access to international capital markets, instruments available to DAB for intervention mainly consist of sales of foreign exchange (previously purchased from the government, donors or other official entities) and sales of central bank marketable notes. When strong pressures resulting from emigration and cash outflow led to a steep 17% year-on-year depreciation of the Afghani (AFN) in December 2015, DAB supplied foreign exchange to mitigate pressures and smooth out volatility.

Although the IMF has highlighted DABS' achievements in maintaining a sufficient foreign exchange reserve and meeting structural benchmarks including currency reporting, asset classification and provisioning, it has also expressed concerns that exchange rate pressures could re-emerge as a reflection of decreasing aid and accelerated outflow of migrants. As a consequence, the currency risk remains high.

Land issues: Land rights and wayleave (right of way) risks are further causes for concern as land titles/ rights in Afghanistan can be extremely difficult to determine (due to lack of documentation) and therefore often present a source of conflict between tribes, families and individuals. Afghanistan has a deeds registration system covering less than 10 percent of rural property while only 30 percent of urban property is covered by legal deeds.

In response to the long-standing problem around land ownership and land rights, the responsibility for all land-related issues has been consolidated under the Afghanistan Independent Land Authority, Arazi. The expansion of Arazi is part of the ongoing efforts for a gradual shift from a courts-based formal titling and registration system towards an administrative land administration system (under Arazi) in collaboration with communities for the administration of land rights.

While the shift is mapped out, the status of the institutional change is not clear, and developers currently still have to go through a court-based process.

6.4 Financing Barriers

***Lack of commercial finance**:*[71] A major bottleneck for investors to engage in renewable projects is the lack of both international and domestic commercial finance in Afghanistan. The country continues to rely on concessional finance from DFIs and bilateral partners.[72] Banking is also highly centralized, with a majority of total loans made in Kabul Province. The difficulty of accessing credit through banks and other formal financial institutions leaves most existing firms dependent on the informal financial sector (family funds, retained earnings etc.)

Lack of private commercial risk insurance/guarantees: Private commercial risk insurance (e.g. to cover construction permitting and delay risk, contractors' all risk (CAR), technology/O&M risk is presently not available in Afghanistan. In comparison to donor-funded guarantee and insurance programs which address the key risks including transfer restriction, expropriation, war and civil disturbance, and breach of contract, private insurers offer a potentially broader range and flexibility of cover. Furthermore, some types of political risks are only insurable through private insurers, e.g. kidnap/ransom/extortion (KRE) coverage.

Limited availability of flexible microcredit facilities (for off-grid projects): In countries, where rural electrification plans have successfully rolled out, the most important enabler was the existence of both access to flexible microloans, and a functioning low-cost (mobile) payment infrastructure, which is currently being adopted in Afghanistan.

Although eight Micro Finance Institutions (MFIs) are currently active in the country, specific loan products for solar appliances and mini-grid systems are currently only piloted by First MicroFinance Bank Afghanistan (FMFB-A) and the non-profit microfinance institution Foundation for International Community Assistance (FINCA) Afghanistan, both of which have offices in Kabul and Herat, and across the Northern provinces (FMFB-A also operates branches in Bamyan). While their expansion of services is a positive development, access to microfinance for off-grid lighting remains a major challenge in southern Afghanistan.

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[71] 'commercial finance' shall refer to debt and equity finance provided by a financial institution, which subjects the borrower to the terms of the market. Instruments include commercial bank loans, project or cooperate bonds and private equity. In Afghanistan, commercial finance may be conventional or compliant to Sharia law.
[72] 'concessional finance' shall refer to lending extended by creditors at terms that are below market terms with the aim of achieving a certain goal.

6.5 Legal and Regulatory Barriers

No renewable regulatory framework securing obligation to take and providing tariff: There are no rules that guarantee the off-take of renewably generated electricity. Although the Renewable Energy Policy[73] refers to off-take obligation and the provision of tariffs, it only *encourages* DABS to take generated electricity without mandating it. Without such a framework that would ensure investors off-take of their electricity, it is unlikely that many renewable projects will materialize. Under current conditions, off-take obligation has to be negotiated with DABS in the specific agreements (PPAs) for each project.

Lack of clarity over the permitting process: The deficiency of a clear legal and regulatory framework leaves the permitting process for various types of power projects unclear and very difficult to comprehend, which deters investment. Afghanistan has a pluralistic legal system that consists of Islamic, statutory and customary rules, which requires additional efforts on the part of foreign entities to navigate. Contract law has been defined in the Afghanistan Commercial Code 1955 and the Afghanistan Civil Code 1977. Under these, parties can enter into a contract on any commercial subject matter provided that the subject matter does not contradict the law, public policy, or Sharia law. Despite the prevalence of a formal justice system, formal and informal dispute resolution systems co-exist in the country. As a consequence, it is currently not clear what the process to obtain permits or the general requirements to comply with corresponding laws are.[74]

Lack of framework for mini-grid and standalone (off-grid) systems: There are no private investments into mini-grid and stand-alone systems in Afghanistan. In order to facilitate independent development of off-grid projects, an effective framework for mini-grid and stand-alone systems must be created first. While mini-grids can legally be owned and operated by private operators, which can charge a different tariff from the national tariff, essential regulation is still lacking. This includes any type of financial incentives, and regulation to differentiate between mini-grid sizes and to clarify procedures for consumers to get connected, and procedures to be triggered when the interconnected grid reaches a mini-grid.

For stand-alone systems, there are two programs to develop and support stand-alone systems, the National Solidarity Program (NSP) and the National Area-based Development Program. However, neither of them contain regulatory provisions for duty exemptions and subsidies, technical standards or certification systems.

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[73] The Renewable Energy Policy sets the goals for a first term from 2015 – 2020 and a second term from 2021 – 2032.

[74] The government has announced plans to merge these systems into one; however, no information is available on what a merged system is supposed to look like.

6.6 Options to Address the Key Risks and Barriers

While it is important to address in the long run key risks and barriers to create an enabling environment that will attract private investments for independent power projects (IPP), there should also be a focus on short-term measures which could draw in private investment in spite of the presently existing risks and barriers. For this reason, the following sections first discuss enhanced use of presently available financial resources, then outline immediate actions to facilitate investments under current conditions, and finally introduce options to overcome structural, regulatory, legal barriers for a viable investment climate in the long run.

6.6.1 Improve utilization of available financing and risk mitigation instruments

As several donor programs in Afghanistan focus on enabling private-sector led growth, concessional finance options have been developed accordingly. These concessionary sources both enable risk mitigation and offer diverse business opportunities including tenders for donor-funded projects, grant assistance for feasibility studies, technical assistance and pilot projects. Through coordination between all involved state agencies, donors, and the private sector, the utilization of these available resources could be significantly improved.

Map the sources of funding: In Afghanistan, there is a range of concessional financing instruments which can be applied to support the development of renewable energy projects. For project investments, loan and equity finance as well as grants for project preparation activities are available. Instruments to leverage private investments can be broadly grouped into those used to overcome financing barriers (such as guarantees and credit enhancements); those used to address the specific risks affecting project related investments (such as risk insurances); and those that address both simultaneously (e.g. technical assistance for capacity building to improve regulatory framework). These instruments can in turn be distinguished by the level of risk assumed by the funding entities, and by the level of leverage (the extent to which public funding mobilizes private finance) involved.

The sources of concessional funding are multilateral DFIs and bilateral donor institutions. Among active multilateral and bilateral organizations are the Asian Development Bank (ADB), International Finance Corporation (IFC), International Monetary Fund (IMF), Japan International Cooperation Agency (JICA), Kreditanstalt für Wiederaufbau (KfW), Overseas Private Investment Corporation (OPIC), United States Agency for International Development (USAID), U.S. Trade and Development Agency (USTDA), and the World Bank.

The **ADB** is Afghanistan's largest development partner in energy: in 2016, it approved a $415 million grant to boost Afghanistan's energy supply and strengthen the country's cross-border trade in energy. Energy infrastructure projects include the construction of 1,460 km of power transmission lines, 16 substations, and 143,000 new power distribution connections to strengthen the country’s energy supply chain. ADB further provides guarantees to cover political risk, and nonpayment by the borrower or issuer (partial credit guarantee).

IFC provides debt and equity financing. IFC**’s** Afghanistan portfolio stands at about US$ 54 million and Includes investments in the financial markets (First Microfinance Bank, Afghanistan International Bank). For example, IFC has played a key role in providing support to develop the country’s first IPP, the Mazar-e-Sharif Gas-To-Power Project. IFC has also launched the pre-implementation phase of the Lighting Afghanistan Program, which aims to expand the off-grid market and to facilitate access by 180,000 households to affordable solar lighting solutions.

JICA’s Assistance Package to Afghanistan includes infrastructure and energy development, particularly hydro and PV systems.

Germany supports energy development through loans by the German development Bank **KfW** as well as projects by the implementing agency **GIZ**. Between 2007 and 2015, GIZ constructed ten mini-hydro plants and two research PV plants in the northern provinces. For German businesses and subsidiaries, the government also provides political risk insurance through PwC.[75]

OPIC is an independent agency of the U.S. Government that offers specialty insurance (stand-alone terror/sabotage and political risk coverage), loans and guarantees to help U.S. businesses of all sizes invest and compete in more than 140 countries worldwide. It has shown longstanding commitment to renewable energy projects and has expanded its renewable energy services in rural areas, including the installation of a one-megawatt solar power system in Bamyan.[76]

USAID plays a major role in reconstruction and capacity building effort, including SME development, infrastructure and energy. The largest ongoing projects for (energy) infrastructure include the Kajaki Dam Hydropower Plant; the Power Transmission Expansion and Connectivity (PTEC) program, which includes support to development of a 10 MW solar power plant in Kandahar.

USTDA provides grants directly to overseas sponsors who in turn select U.S. companies to perform agency-funded project preparation activities. An overseas sponsor is a local entity, public or private, with the decision-making authority and ability to implement a project. Key activities include feasibility studies and pilot projects, technical assistance and training programs. USTDA has increased the number of pilot projects it will fund to test and scale innovative U.S. solutions, particularly in energy and ICT.

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[75] Agaportal (2017), *Investment Guarantees of the federal Republic of Germany*, https://www.agaportal.de/en/main-navigation/investitionen-investitionsgarantien/grundlagen-investitionsgarantien/grundzuege-investitionsgarantien

[76] OPIC (2012), *Supporting Investment In Afghanistan*, https://www.opic.gov/blog/events/supporting-investment-in-afghanistan

The **World Bank** provides grants and partial risk guarantees (PRG) through the International Development Association (IDA), and technical assistance. In Afghanistan, it further administers the multi-donor Afghanistan Reconstruction Trust Fund (ARTF), which provides coordinated financing of unfunded priority expenditures in Afghanistan's reconstruction program as well as supporting the recurrent costs of government.

In the absence of private commercial risk insurance, e.g. to cover construction permitting and delay risk, contractors' all risk (CAR), technology/O&M risk, it is therefore all the more important to facilitate and scale up the utilization of available Partial Risk Guarantee (PRG) options through **IDA** to backstop financial obligations, and Political Risk Insurance (PRI) made available through the Multilateral Investment Guarantee Agency (MIGA).

Utilize guarantees and credit enhancements at macro level and project level: At the macro or national level, to demonstrate to investors that the security and political risks are manageable, the government should identify potential projects, actively engage with eligible developers and investors and provide them with information[77] on risk mitigation instruments made available for renewable energy projects in Afghanistan through ADB and the World Bank[78] Furthermore, risk-mitigating financial instruments, which are available from several institutions, including MIGA, should be better known, understood and utilized by investors.

At the project level, developers and investors should make every effort to understand, and where possible, mitigate the project risks. Access to insurances or other strategies (e.g. indexation of foreign currency denominated project components and convertibility of local currency to a hard currency) for risks which cannot be mitigated through standard practices (e.g. warranties, EPC or turnkey contracting) could be created in cooperation with donor institutions.

For existing insurance programs, it is vital to communicate the respective assessment criteria for coverage (including economic and financial viability of the project; home country impacts; host country development) to prospective and actual investors.

Existing programs include the IDA18 IFC-MIGA Private Sector Window (PSW), and the scaled up regional window in IDA18, through which the Afghan government is in a stronger position to offer terms for backstopping DABS' off-take obligation in the implementation agreements for IPPs, which should be clearly communicated to potential foreign investors. Partial risk guarantees

[77] As reported by the Afghanistan Chamber of Commerce of Industries (ACCI), awareness of available guarantees and risk insurance products is still very low among Afghan businesses.
[78] Called 'Partial Risk Guarantee (PRG)' and the World Bank and 'Partial Credit Guarantee (PCG) by ADB. Other countries may also offer investment guarantee programs. However, due to Afghanistan's risk category, they are mostly only covering short-term transactions.

(PRG) to backstop the government's /DABS' contractual obligations are available through IDA or ADB.

Projects eligible for PRG may be identified through sector discussion between the funding institutions and the government or, alternatively, through transaction advisors. For US businesses, OPIC's loan and guarantee programs under the Investment Incentive Agreement (IIA) should be considered.

In the medium to long term however, DABS' capacity to operate and maintain the power system and manage new investments should be further strengthened though targeted programs.

6.6.2 Take immediate actions to facilitate investments under current conditions

As a first step, the government should identify priority projects, which are to be developed preferably with private sector investment, and provide the arrangement for security personnel on-site. Next, the government should determine the most suitable approach for each of the identified projects. Three approaches are appropriate to the Afghanistan contexts: IPP through 'regulation by contract', a standardized 'one stop shop' approach for grid renewable projects, and Pay-As-You-Go (PAYG) for off-grid projects.

IPP through 'regulation by contract'

According to the Renewable Energy Policy, the private sector is encouraged to develop and manage renewable energy projects on a Built-Own-Operate (BOO) basis. As new laws and regulatory agencies will require time and resources to fully develop necessary capacities, past and ongoing PPA negotiations have been based on the 'regulation by contract' concept, i.e. pre-specification of regulatory treatment in the absence of formal regulatory frameworks.

Through the 'regulation by contract' approach, one or more written agreements between a private company and a government entity are developed, in which the government entity pre-commits to a specified regulatory system that establishes how risks will be allocated and how retail tariffs will be set for a multi-year period. The contract is specified prior to receiving privatization bids so that bidders can estimate their likely future stream of revenues.

Box 1 provides an example of a thermal project being prepared in Mazar-e-Sharif.

Box 1. The Mazar-e-Sharif Gas-To-Power 50 MW Project

Afghanistan's first IPP currently under preparation is a 50 MW gas-fired power plant near Mazar-e-Sharif, the Mazar-e-Sharif Gas-To-Power Project. The total project costs are expected to be around US$75 million and to be financed on the basis of a 70:30 debt-to-equity ratio. Ghazanfar group and IFC are the equity investors, while IFC also provides US$44 million in debt. Under the PPA, which had been developed in cooperation with IFC, the project duration is 20 years which are extendable by 10 years upon mutual agreement. Dispatch risk will be mitigated through a take-or-pay obligation[79] for 80% of annual contractual quantity (ACQ) by DABS.

The off-take risk will be mitigated through a sovereign guarantee: DABS and Ministry of Mines and Petroleum (MoMP)/ Afghan Gas Enterprise's (AGE's) financial obligations are to be guaranteed by MoF on behalf of the government. The guarantee is to be backstopped by a PRG (of proposed US$30 million) provided by the World Bank through IDA. Political Risk Insurance (PRI) for potential foreign equity co-investors in discussion with the Ghazanfar Group will be provided through MIGA.

The implementation of the project will be governed by the following key agreements among the key stakeholders:

- PPA to be signed between the developer, the Ghazanfar Group based in Mazar-e-Sharif and DABS.
- Gas Supply and Purchase Agreement to be signed by the MoMP, the AGE, and the IPP Developer
- The Implementation Agreement with the signatory parties being MEW, MoF, AGE, MoMP and IPP Developer

The construction of the project is expected to be implemented under a turn-key Engineering, Procurement, and Construction (EPC) contract. The World Bank Group Performance Standards will be used for the project. Once successfully completed, the PPA negotiated for the Mazar project could potentially be modified to serve as a regulatory working model for renewable energy IPPs.

Regulation by contract, where the Government has a financial stake in the venture can help to address political, legal and commercial risks where legal and institutional systems are not fully developed and courts cannot be relied upon to protect property rights. Letting the government hold residual rights in the enterprise, or committing them to ensure its cash-flow through Power Purchase Agreements (PPAs) may serve as a mechanism for avoiding expropriation and ensuring that the viability of the project is maintained. This is especially true if PPA obligations are backed by guarantees by credible international agencies. In such circumstances, the expectation of future profits and/or risk of incurring financial obligations can exert a stronger discipline on the public authority than fear of legal sanction.

One-Stop-Shop as a standardized approach

A standardized one-stop-shop (OSS)[80] scheme combining financing, risk mitigation facilities, and institutional support could lay the necessary foundations to catalyse private sector investment. An OSS could enable a speedy delivery of competitive tariffs, reputable developers and contractors, high quality installations and certainty on delivery by a set date. In parallel, it can provide investors/developers with certainty of process, low transaction costs, a robust and bankable

[79] A "obligation to take" or "take or pay obligation" stipulates that all power generated, or percentage thereof, must be purchased by the off-taker and accepted by the grid.
[80] A 'one-stop-shop' coordinates several instruments under a single product/facility to address multiple bottlenecks and streamline processes.

contractual package and a de-risking of their investments in the respective markets. Moreover, it could allow procuring governments and market participants (investors, advisors, suppliers) to gain expertise and build new capacities.

Box 2. Scaling Solar

Scaling Solar was developed by the World Bank Group as a one-stop-shop solution for undeveloped solar markets faced with high risks, lack of a clear contractual framework and public procurement rules.

In Zambia, the first country to mandate IFC to roll out Scaling Solar, auctions in 2016 for two projects resulted in a 6.02 US¢/kWh tariff by the solar developers NEOEN S.A.S. / First Solar Inc. and a 7.84 US¢ /kWh tariff by Enel Green Power S.p.A, which make the projects the lowest-cost solar power in sub-Saharan Africa to date. The two tendered projects (for the development of 50 MW utility-scale solar power systems each) are the countries first large scale solar IPPs

Scaling Solar as an One-Stop-Shop (OSS) model

Since Afghanistan is a single-buyer market with a weak off-taker and only one IPP project under development, it meets the key criteria for an OSS approach along the lines of Scaling Solar. Although further work to determine the most suitable sites is still underway, the technological requirements for competitive solar energy are met. As the Afghan government has already expressed interest in the Scaling Solar approach, the country's eligibility is currently subject to further analysis.

Pay-As-You-Go

Pay as you-go (PAYG) is a revenue model that has emerged and proven to be viable with customers in emerging markets, where it lets buyers pay small amounts for utilities 'on-demand'. The systems are sold against a small upfront payment and regular 'top-ups', ideally sent via low-cost mobile money services. Several start-ups have begun to combine sales of such systems with consumer loans. The industry has attracted financing of more than $360m over the past five years, with more than half of that amount in 2015 alone.

PAYG operators still primarily focus on East and West Africa. What holds companies back from entering the Afghan markets is market intelligence (reliance on third-party information is particularly high in Afghanistan) and quality assurance.[81] In Afghanistan, such bottlenecks are being addressed by Lighting Afghanistan, one of the country programs under Lighting Global, which seeks to provide market intelligence and to ensure that both consumers and investors understand the market dynamics.[82] Next to the facilitation of Business Development, the program promotes Consumer Awareness: its first consumer awareness campaign was launched in Kabul in February 2017. The other central component of the program is the provision of quality assurance. Manufactures can get their products tested against international standards and distributors can acquire quality-verified products that microfinance institutions can consider financing for the lighting industry.

While there is no PAYG solar company offering services in Afghanistan to this date, a prepaid metering model for collecting revenue has been implemented for the Bamyan Renewable Energy Program (BREP), which differs from the post-paid analogue metered collection system common in the rest of Afghanistan. The 1 MW off-grid PV Diesel Hybrid system was installed for the community of Bamyan in central Afghanistan in 2013 and was financed by New Zealand firms Sustainable Energy Services and NETcon. The BREP generation system is comprised of four generation sites and provides 230V /50 Hz electricity to 2,400 households in several neighbourhoods around the Bamyan City area.

6.6.3 Overcome structural, regulatory, legal barriers for a viable investment climate in the long run

To create a robust and enabling environment for private investment, establishing the necessary legal and regulatory framework must be accompanied by an upgrade of the institutional and technical capacity of the public sector.

Improve technical and institutional capacity of MEW, DABS and other key institutions

[81] For a better understanding of possible PAYG business model variations and their implications, six alternative PAYG solutions and lessons learned have been compared under the Renewable Energy Microfinance and Microenterprise Program (REMMP). http://18microcreditsummit.org/wp-content/uploads/2015/12/REMMP_Briefing_Note_PayGo.pdf

[82] Lighting Global (2015), *Quality Assurance Policy for PAYG Systems,* https://www.lightingglobal.org/news/quality-assurance-policy-for-payg-systems/

The institution responsible for directing Afghanistan's renewable energy resources and accelerating market development for renewable energy technologies is the **Renewable Energy Department (RED)** under the **Ministry of Energy and Water (MEW)**. As RED is mandated to track all activities and developments related to the renewable energy sector as well manage related technical data, its staff should be sufficiently trained and able to draw on the tools and infrastructure to collect and process related data (e.g. GIS maps, customer databases, and cost analyses).

Other key institutions in the renewable energy sector, whose capacities should be expanded in a similar manner, include the **Renewable Energy Coordination Committee (RECC)**, which coordinates efforts of MEW, MRRD, and DABS in the field of renewable energy.

The **Afghanistan Renewable Energy Union (AREU)** which assists international investors and stakeholders in investment procedures and advises on legislation should have the resources to provide information on grid-connected, mini-grid and off-grid policies and requirements. To navigate developers through the intricate and changing permitting process, AREU could provide checklists for all necessary permits including descriptions of the procedure, estimated time to complete and associated costs.

To expand local land registration, the internal capacity of **Arazi** (the Independent Land Authority) offices needs to be increased. More precisely, local Arazi staff should be sufficiently trained technically to conduct mapping, land survey and carry out administrative tasks to record land title, as well as culturally to engage with community-based forums to ensure fair, accurate, and legitimate titling. A range of community-based land registration processes is being applied globally. These models should be explored for possible application in Afghanistan.

The state-owned utility DABS should further build up capacity to operate and maintain the power system and manage new investments. To increase its commercial efficiency ratio, metering, billing, and collection could be further improved through technological advancement and training.

Create enabling regulatory and legal environment through legal reform, strong enforcement and improved institutional coordination

To build an effective regulatory framework, the respective laws and policies need more substance to secure risk mitigation for investors and developers. For instance, given that off-take risk is among the greatest concerns for investors, the legal framework should include a provision for off-take obligation. Laws and regulations that already contain significant, legally binding provisions can only be effective when proper monitoring and enforcement mechanisms are in place. Currently, under the regulatory framework for PPPs, established in September 2016 in the form of a Presidential Decree,[83] a newly created Central Public-Private Partnership Authority has been mandated to provide operational support including technical advice to the entities and forwarding project proposals to the High Economic Council for approval, modification or rejection. While the creation of a PPP law and authority is to be understood as a positive development easing the bureaucratic burden, it is not clear what the capacities are to enforce the decree and run the newly created PPP Authority.

Lastly, it is vital to ensure that improvements in the legal and regulatory environment and institutional capacities are clearly communicated to potential foreign investors. An important recent achievement is Afghanistan's WTO accession in 2016, which signals its ability to meet international and regional standards. The government should develop a plan within their post-accession strategy[84] to draw in private insurance companies to complement PRG and PRI, which would unburden negotiation efforts for contracts and agreements.

6.7 Summary and Recommendations

In light of the current security situation, technical and financing challenges, commercial risks and lack of an effective legal and regulatory framework to attract private investments into the renewable energy sector, the government should take necessary actions to create a viable, enabling environment for private investments in the long run, but also focus on projects that can be developed and implemented under present circumstances. A central component of all actions should be an intensified utilization of available guarantees, credit enhancements and other financial instruments.

In the short term, measures that enable projects in the current environment are:

- Develop a contract structure in which risks are efficiently allocated between the developer, off-taker and the government
- Through this contract structure identify priority projects; provide security for the development and operation of these projects; and provide guarantees to cover key risks including off-taker creditworthiness, land access and currency risk
- Consider blending with donor funds to make financing more attractive and viable
- Develop standard documents, especially legal agreements and bidding documents, based on the experience of the Mazar IPP, Scaling Solar and other successful initiatives
- Develop pilots for small (mini-grid, off-gird) projects through DFI funding.

[83] The PPP Law is available in English at :
http://mof.gov.af/Content/Media/Documents/PPPLawOfficialEnglish1110201693647139553325325.pdf
[84] WTO (2016), *Remarks By H.E. Humayoon Rasaw Minister Of Commerce And Industries Of The Islamic Republic Of Afghanistan At The Post-Accession Forum: Maximising The Benefits Of Wto Membership Wto Membership Of Afghanistan And Liberia 14th Ministerial Conference Nairobi, Kenya July 19, 2016*,
https://www.wto.org/english/news_e/news16_e/rasawspeech21716_e.pdf

In the long term, resources should be allocated to:

- Enhance the significance and substance of the existing law and policies
- Ensure that there are sufficient monitoring and enforcement mechanisms in place, which make laws effective
- Strengthen a clear coordination between all involved ministries and agencies and gear policies to local conditions and demands for grid (e.g. create laws for off-take obligation, priority dispatch etc.) and off grid (e.g. create standards and incentives for mini-grid and off-grid systems)
- Upgrade and expand technical and institutional capacities through training and introduction of programs/tools to better manage and provide relevant systems and data.
- Develop demand-driven bottom-up strategies for rural electrification (mini-grids and stand-alone solutions)
- Provide local financial institutions with the tools and expertise needed to lend to solar, wind, hydro developers.

7 VULNERABILITIES TO CLIMATE AND NATURAL DISASTERS

7.1 Introduction

This chapter[85] analyzes the resilience to climate and natural hazards of the current energy system in Afghanistan, and assesses the resilience of a potential future energy system given the planned construction of new power plants, substations and transmission lines. It discusses principles, risk management framework, and preliminary projections to help guide the choice and design of power systems by incorporating the potential impacts of climate change to resource availability (e.g., how climate change will impact water supply to hydropower, or availability of solar radiance to solar power production), and a vulnerability assessment to natural disasters (e.g., the susceptibility to flood, or the risk of landslide, of a potential site).

7.2 Climate Change in Afghanistan

Afghanistan has a continental climate, semi-arid to arid, classified within the 'Desert' or 'Desert Steppe' climate classification scheme[86]. Models that project changes in global vegetation in response to increased CO_2 indicate that desert, or arid, communities will be less affected by climate change compared to the semi-arid areas, where agriculture, natural grasslands, livestock, and water resources are the most vulnerable sectors[87].

The economic activities of arid and semi-arid lands of the region are mainly based on agriculture and livestock grazing in rangelands. These ecosystems are very vulnerable to climate conditions such as high temperatures and droughts, especially because of depleting soil water and nutrient reserves, requiring water resource management, stock management, and integrated agro-ecosystems.

Spring growth is expected to start earlier because of higher temperature, especially in regions with cold winters, resulting in earlier depletion of water reserves accumulated over the winter, with the risk of even longer periods of potential drought, and a potential reduction in animal productivity, including wool production. In some areas, warmer weather may lead to an increase in fire frequency, which may reduce local precipitation because fire-emitted aerosols will produce smaller cloud droplets that are less likely to fall as rain. Human settlements and commercial cultivation have degraded land and reduced vegetation cover. Less vegetation

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85 The chapter is adapted from an internal WB paper *Vulnerabilities to Climate and Natural Disasters of the Energy System in Afghanistan* published in May, 2017

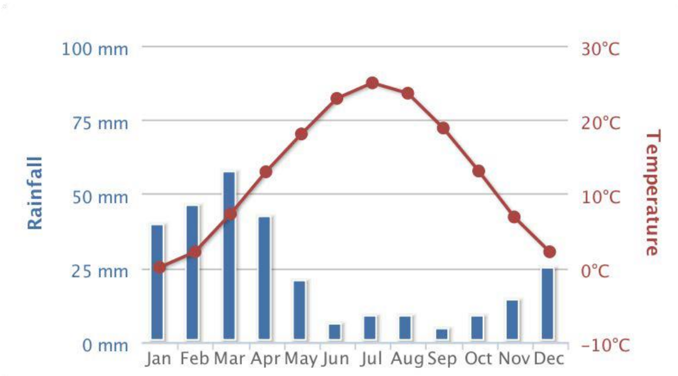
86 IPCC. (1997). *The Regional Impacts of Climate Change: An Assessment of Vulnerability.* (M. R. R.T.Watson, Ed.) Cambridge University Press

87 Smith, J., Huq, S., Lenghart, S., Mata, L., Nemesova, I., & Toure, S. (1996). *Water resources. 1. In: Vulnerabilities and Adaption to Climate Change: a Synthesis of Results from the U.S. Country Studies Program. .* Washington, DC, USA: U.S. Country Studies Program.

increases soil-moisture evaporation, erosion, and siltation, resulting in poorer water quality[88].

Temperature will increase 1.4-4.0 °C by the 2060s. Temperature varies between the lowland plains to the south and the mountainous regions in the north. The lowland plains experience wide seasonal variations in temperature, with average summer (June-August) temperatures above 33 °C and average winter (December- February) temperatures around 10 °C. The high-altitude regions of Afghanistan experience lower annual temperatures, with summer temperatures averaging 15 °C, and winter temperatures below 0 °C in the highest areas. Average annual temperature over the country increased by 0.6 °C between 1960 and 2008. Figure 7.1 shows the average Monthly Temperature and Rainfall for Afghanistan over the period 1960-1990.

Figure 7.1 Average monthly temperature and rainfall for Afghanistan from 1960-1990.



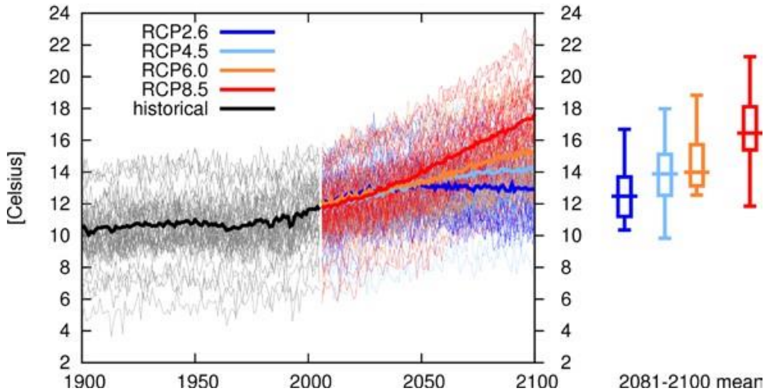
(Source: WBG, 2017)

Average annual temperature is projected to increase between 1.4 °C and 4.0 °C by the 2060s, and between 2.0°C and 6.2 °C by the 2090s. Spring and summer are projected to experience the fastest rate of warming with quite uniform warming over the country's regions. Figure 7.2 shows a subset of the average temperature historical data reported by the IPCC in the Assessment Report 5 and the forecast produced by the multi model simulation project CMIP5 [89] relative to Afghanistan for all four emission scenarios.

[88] IPCC. (1995). *Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses.* Edited by R.T. Watson, M.C. Zinyowera, R.H. Moss, D.J. Dokken, Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press

[89] IPCC. (2013). *Climate Change 2013: The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Figure 7.2 Average annual temperature in Afghanistan from 1900 to 2016 (black lines) and CMIP5 forecasts to 2100 for four emission scenarios (colored lines). (Note: Mean temperature and variance for the period 2081-2100 for all scenarios are shown to the right of the framed plot. Data extraction and plot generation from KNMI (2016))



As a result of the projected increase in the mean annual temperature, Afghanistan Initial National Communication (AINC) to the United Nations Framework Convention on Climate Change (UNFCCC) in Paris warns that by 2060 "large parts of the [country's] agricultural economy will become marginal without significant investment in water management and irrigation."[90]

Precipitation - Rainfall is low over most of the country, but it is very variable seasonally and interannually. Most precipitation occurs in the northeastern mountainous regions, which receive 992.1 mm per year of annual precipitations; large parts of the country receive very little to no precipitation, with high unpredictability in the arid lowlands. The southwestern regions receive the lowest annual precipitation of 51.56 mm per year. Areas in the Eastern provinces of Kunar, Nuristan, Laghman, and Nangarhar, which are located on the boundary of the monsoon regime affecting the Indian subcontinent, can receive large amounts of precipitation during the summer (1,200 mm, or about 5 times the country's average).

Most precipitation falls as snow in high altitude areas, during November through April, with peaks during February and March. Rainfall typically occurs in the high northern latitudes from March to April. There is little or no discernible trend in annual precipitation since the beginning of the 20th century. Forecasts relative to Afghanistan for all four emission scenarios indicate no clear change in future precipitation in any scenarios.

Extreme hot days will increase. Since 1960, the frequency of hot days and nights in Afghanistan has increased in each season, while the frequency of cold days and nights has decreased[91]. This trend is expected to continue in the future. The frequency of hot days and

[90] AINC. (2012). *Afghanistan Initial National Communication To the United Nations Framework Convention on Climate Change.* Islamic Republic of Afghanistan. National Environmental Protection Agency
[91] CCKP. (2017). Retrieved from The World Bank Group: Climate Change Knowledge Portal:

nights per year are projected to increase throughout the middle and late 21st century, whereas cold days and nights are projected to decrease in frequency and become exceedingly uncommon.

Throughout the middle and late 21st century, the average heat wave duration is projected to increase, with the eastern regions projected to experience the largest change, while the frequency of frost days is projected to decrease, with the mountainous areas of eastern and northeastern Afghanistan projected to experience the largest decreases in frost days[92].

Most glaciers are retreating. Landsat and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) imagery acquired in 1976, 1992, 2001 and 2007 on a sample of fifty-two Alpine glaciers of various sizes, altitudes and orientations from Eastern Hindu Kush Range of Afghanistan and Pakistan show that 76% of the sampled glaciers retreated, 16% advanced and 8% exhibited relatively stable terminus conditions. Similar results have been obtained in other regions, where 93% of the sampled glaciers in the Wakhan region of Afghanistan[93] and 74% of the sampled glaciers in the Hindu Raj of Pakistan retreated[94] [95].

Future climate projections obtained using CORDEX South Asia models for the period 2021-2050 for a moderate emissions scenario (RCP4.5) indicate that temperatures will increase more over the mountainous areas of the country than in the southern lower altitude areas. Higher temperatures in mountainous areas will accelerate glacier melting, increasing also the risk of glacial lake outburst floods (GLOF), which occur when the moraine walls which dam a glacial lake breaks[96]. The forecasted increased glacial melt would lead to a temporary increase of summer river flows for a few decades, followed by a reduction in flow as the glaciers disappear. Loss of glacier mass and snow cover are projected to accelerate throughout the twenty-first century, reducing water supplies and hydropower potential[97]

7.3 Impact Assessment of Climate and Other Natural Hazards

The World Bank Group and the Global Facility for Disaster Reduction and Recovery (GFDRR) conducted an assessment of risks from major natural hazards and disasters in Afghanistan,

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http://sdwebx.worldbank.org/climateportal/

92 ibid

93 Haritashya, U., Bishop, M., Shroder, J., Bush, A., & Bulley, H. (2009). Space-based assessment of glacier fluctuations in the Wakhan Pamir, Afghanistan. *Climate Change, 94*, 5-18

94 Sarikaya, M. A., Bishop, M. P., Shroder, J. F., & Olsenholler, J. A. (2012). Spacebased observations of Eastern Hindu Kush glaciers between 1976 and 2007, Afghanistan and Pakistan. *Remote Sensing Letters*, *3*(1), 77-84.

95 ICIMOD. (2011). *The status of glaciers in the Hindu Kush-Himalayan region.* Bajracharya, SR; Shrestha, B (eds) .Kathmandu, Nepal: International Centre for Integrated Mountain Development

96 WFP. (2016). *Climate Change in Afghanistan.* World Food Programme.

97 Singh, S., Bassignana-Khadka, I., Karky, B., & Sharma, E. (2011). *Climate change in the Hindu Kush Himalaya region. The state of current knowledge.* Kathmandu, Nepal: International Centre for Integrated Mountain Development

including fluvial flood, flash flood, drought, landslides, avalanches and earthquakes[98]. The analysis estimates the probability of occurrence of each hazard throughout the entire territory and produced risk maps. The study includes a preliminary analysis of the costs and benefits of resilient reconstruction and risk reduction strategies. The risk information determined by the analysis is used here to assess the vulnerability of the energy system to natural disasters.

7.3.1 Drought

Afghanistan suffered a severe drought from 1998-2006, and more recently in 2008-2009. Drought can be related to insufficient precipitation (meteorological drought), stream flow (hydrological drought) and soil moisture. Precipitation below normal levels in the winter and early spring season create a shortage of water storage for use throughout the summer season. A dry winter may translate into a small snow pack, low reservoir levels, drying streams, and low water levels in wells. This could cause a shortage of potable and irrigation water, degradation of rangelands and forests, diminished crop diversity and productivity, reduction in livestock and hydropower production[99].

The system has a buffer capacity, and a lack of precipitation may not immediately generate hydrological drought because of storage of water in the subsoil groundwater zone; likewise, hydrological drought may not result immediately in water shortage because of the storage capacity of reservoirs.

The drought risk analysis was conducted using a distributed rainfall – runoff model, which provided the input flow data to a water balance model. Impacts of meteorological and hydrological droughts on water users have been assessed considering three main user types: agriculture (crop production), hydropower production, and domestic, municipal and industrial (DMI) use. The relevant results for the three user types are reported here, as competition for water resources is to be expected between user types.

Urban and rural population in 2015-2016 was estimated based on information from the Afghanistan Central Statistics Organization (CSO). The total population that requires water supply from surface water is projected to increase from 12,191,434 in 2015 to 26,410,673 in 2050. DMI water demand increases from 412 Mm^3 per year in 2015 to about 1,059 Mm^3 per year in 2050.

A meteorological drought can be quantified as a rainfall deficit, which in any given year can be

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[98] WBG. (2016). *Afghanistan – Multi-hazard risk assessment, cost-benefit analysis, and resilient design recommendations. Final report.* Washington, DC: The World Bank Group.

[99] Bhattacharyya, K., Azizi, P. M., Shobair, S. S., & Mohsini, M. Y. (2004). *Drought impacts and potential for their mitigation in southern and western Afghanistan. Working Paper 91.* Colombo, Sri Lanka: International Water Management Institute.

expressed as the difference between the average annual precipitation in that year and the median annual precipitation over a representative number of years (a reference time period). The rainfall deficit in Afghanistan was calculated with respect to a reference simulated time period of 44 years - from 1958 to 2001 - for a current and a future scenario in 2050, and for several return periods. The estimated rainfall deficit for a 50-year return period along with the current and the future hydro power plants is shown in Figure 7.3 for the current scenario, and in Figure 7.4 for the future scenario in 2050. The analysis shows that the Northern regions have the lowest drought incidence with average annual rainfall lower than about 50% of the median once in 50 years, whereas in the South-Western regions the deficit precipitation can be as high as 87% of the median once in 50 years. In 2050, rainfall deficit increases everywhere, with peaks of 98% once in 50 years in the southern regions. These regions receive less precipitation on average, and have a larger precipitation variability, resulting in a larger probability of meteorological drought.

Different regional climate models produce precipitation forecasts in Afghanistan inconsistent with each other, with some models predicting increased precipitation, and some models a decrease in precipitation. In order to provide a conservative analysis, for the drought risk analysis it was selected a model that produces a future climate scenario where precipitation will decrease in most sub-basins. Reduced precipitation not only decreases the surface water availability, but also increases the agricultural demand for surface water irrigation.

Figure 7.3 Rainfall deficit in the present scenario with respect to the reference period 1958 – 2001 for a 50-year return period (RP), along with current and future hydro power plants

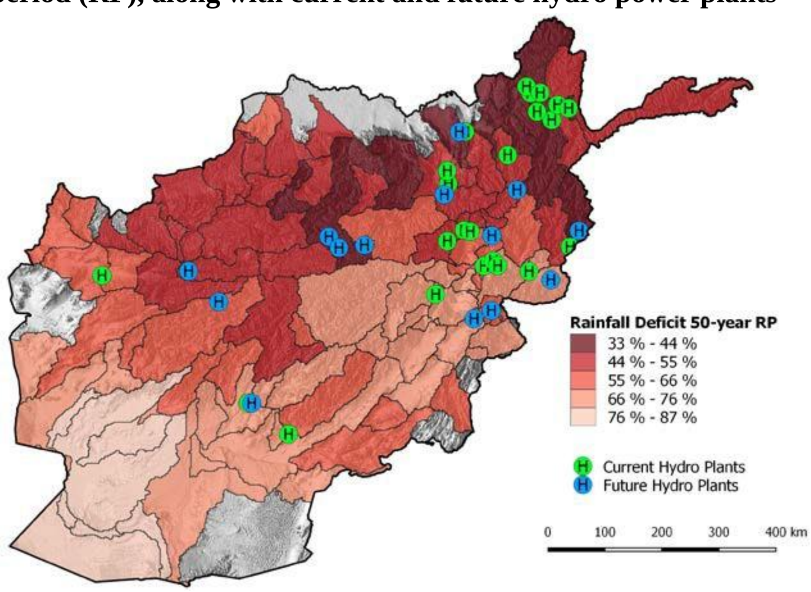
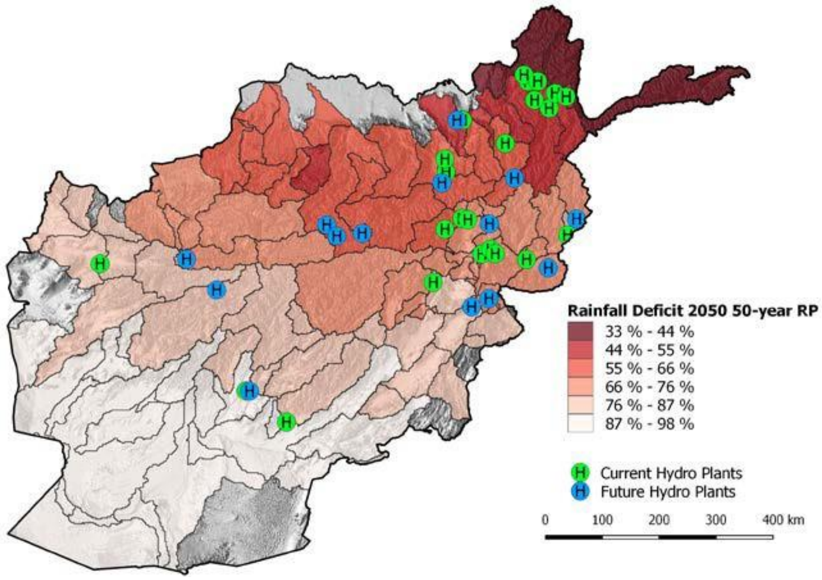


Figure 7.4 Rainfall deficit in 2050 with respect to the reference period 1958 – 2001 for a 50-year return period, along with current and future hydro power plants



Hydro power is particularly sensitive to the impacts of climate change and natural hazards. Changes in precipitation, accelerated mass losses from glaciers and reductions in snow cover throughout the twenty-first century, siltation, increased demand of water for irrigation and drinking water purposes (upstream), and changed seasonality of flows in basins will all have direct impact on the availability of water for hydropower generation. Small hydro powers plants (HPP) and run-of-the-river types are particularly vulnerable as most are sensitive to variations in water flows[100].

Impact of drought on hydropower production was simulated for two reservoirs: Kajaki and Naghlu. Currently, the Kajaki reservoir produces less than 134 GWh once in 10 years, corresponding to 37% of its median production, and a production of less than 43 GWh is to be expected once in 20 years, corresponding to 12% of its median production. The Naghlu reservoir is expected to produce 31% of its median production every 10 years, and to have zero production every 50 years.

Hydropower production in 2050, calculated assuming that future climate follows the dry scenario predicted by the IPSL Earth System model and that population is increasing, is projected to reduce significantly. The Kajaki reservoir is expected to have zero production at least once every 10 years; the Naghlu reservoir would have zero output once every 20 years. Table 7.1 shows the estimated Kajaki and Naghlu reservoirs current and 2050 production for various return periods.

[100] AINC. (2012). Op cit

Table 7.1 Estimated production for the Kajaki and Naghlu reservoirs for various return periods (current v.s. 2050)

Return	**Kajaki**				**Naghlu**			
Period	Current		2050		Current		2050	
(years)	GWh	% median	GWh	% median	GWh	% median	GWh	% median
10	134	37%	0	0%	64	31%	12	12%
20	43	12%	0	0%	51	25%	0	0%
50	41	11%	0	0%	0	0%	0	0%
100	41	11%	0	0%	0	0%	0	0%
250	41	11%	0	0%	0	0%	0	0%

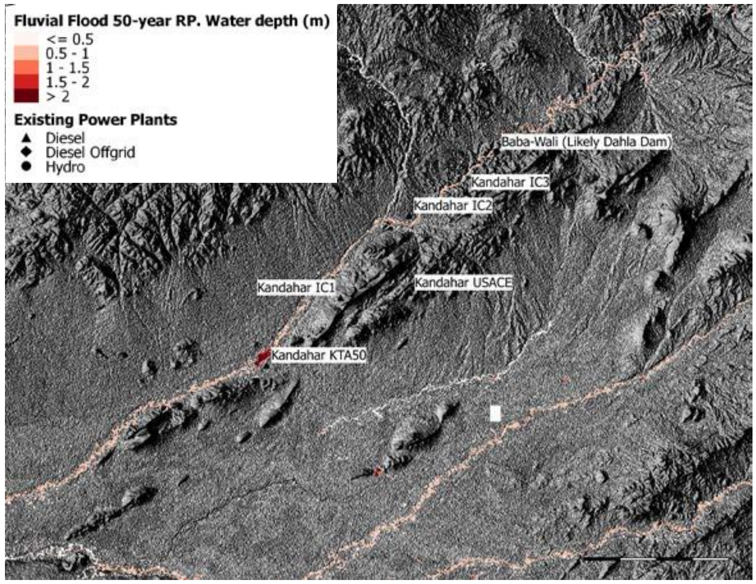
7.3.2 Fluvial flood and flash flood risk

The fluvial flood risk was assessed by a hydrodynamic analysis that estimates river flow, inundation, and flow over floodplain areas resulting from the runoff. The amount of precipitation that comes to runoff was estimated through a hydrological analysis. The analysis includes an assessment of the impacts of a flood to the areas with high damage potential.

The areas subject to fluvial flooding are relatively small, generally extending only a few meters from the river banks. Therefore, the risk assessment for specific infrastructure requires a dedicated local analysis, including the exact location of the infrastructure and a high definition risk map of the area. As an example, Figure 7.5 shows the estimated water depth of fluvial floods with a 50-year return period in southern Afghanistan near Kandahar, where five diesel plants are located near flood prone areas.

The flash flood risk was estimated using a Flash Flood Susceptibility Index (FFSI), based on catchment physiographic factors, drainage network and soil properties. The FFSI is strongly dependent on terrain characteristics, and has therefore a very local nature, displaying rich features and high variability within relatively small scales. The available data indicate on average a higher susceptibility to flash flood of the mountainous regions on the North East of the country, and a null to low spatially-averaged susceptibility in the most southern areas of the country.

Figure 7.5 Detail of fluvial flood assessment and existing power plants in the Kandahar area. Red color represents the estimated water depth of fluvial floods with a 50-year return period.



7.3.3 Landslide Risk

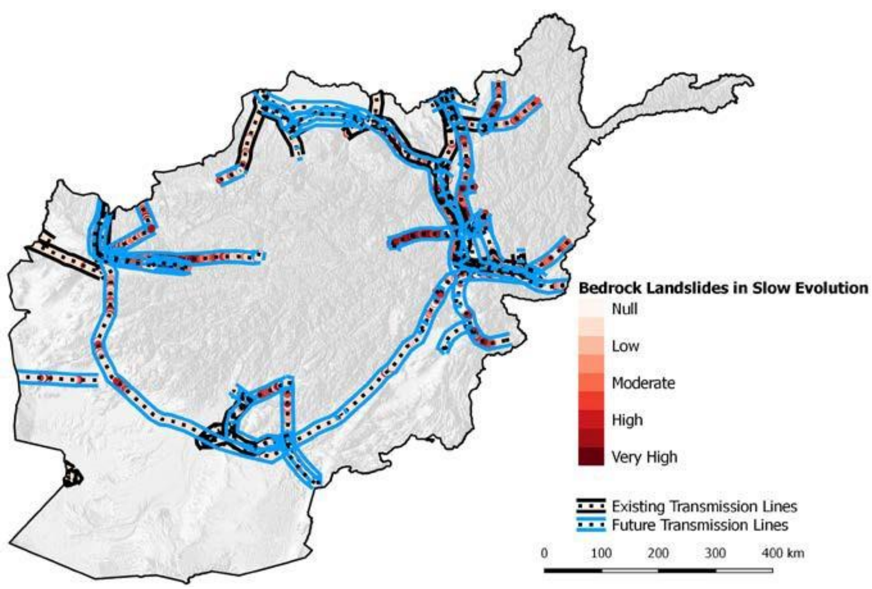
Landslide modeling consists of several phases. First, an inventory of landslides was compiled and spatially overlaid with geological, elevation and land use information. Through a statistical analysis, discriminant parameters (necessary conditions) and predisposing factors causing landslides were identified. Finally, a susceptibility index was calculated for the entire territory depending on the presence and weighs of the parameters.

The landslide risk assessment has been conducted for three different classes of landslides: Bedrock landslides in slow evolution, including: rotational slides, translational slides, earth flows and lateral spreading; Bedrock landslides in rapid evolution, including: falls and toppling: this type of landslides is often induced by earthquakes; Cover material landslides in rapid evolution, including: debris-mud flows.

The impacts of landslides are restricted to small areas of influence. Therefore, the maps of susceptibility to landslide at the national level should be considered as an indication of the susceptibility of the areas where the structures are located or are planned to be located. Hazard assessment for specific structures requires dedicated study at a local level.

Susceptibility to bedrock landslides in rapid evolution is generally limited to relatively small areas in the north east, where susceptibility is generally moderate with a few high peaks. The existing transmission line between Kabul and Khwaja Alwan, and the line between Kabul and Ghawchak are crossing susceptible areas. Similar hazard levels and location apply to the future transmission lines. Bedrock landslides in slow evolution are not strictly limited to mountainous regions, and are more widespread throughout the country. The regions located at the center and north of the country have high susceptibility to bedrock landslides in slow evolution, while moderate to high susceptibility is observed in the north-eastern areas. Several power plants and transmission lines are located in areas of high susceptibility. The existing transmission line north and east of Kabul appear to be the most potentially affected by this type of landslide. The future lines north and east of Kabul, the line between Bamyan and Doshi, and the line east of Herat between Noor-e-jahad and Ferozkoh are located on areas with high to very high susceptibility to bedrock landslides in slow evolution. Details of the levels of susceptibility along those transmission lines paths are shown in Figure 7.6. A large portion of the country is highly susceptible to debris landslide in rapid evolution. For the existing energy system, debris landslide in rapid evolution represent a potential hazard mainly for the transmission lines north of Kabul, and for the southern end of the line between Andkhov and Maymana. Several future transmission lines are also affected, notably all branches east of Herat, and the line connecting Kandahar to Tirinkot.

Figure 7.6 Susceptibility levels to bedrock landslides in slow evolution along existing and future transmission lines paths



7.3.4 Snow Avalanche Risk

Snow avalanche hazard and risk modelling is typically used to assist in spatial land-use planning of settlements, transport routes, electricity transmission lines and other critical infrastructure to limit avalanche risk.

The snow avalanche risk analysis includes collection of historic avalanche data and numerical modeling of the avalanche runout potential and dynamics on a nationwide level. Snow avalanche modeling is based on the analysis of meteorological data, snow properties, recent snow avalanche events in the region. The model produces avalanche hazard maps delineating the likely starting and transition zones of avalanches, including the runout areas of avalanche deposits. In addition, dynamic avalanche modeling provides the dynamic flow properties during runout such as flow and deposition heights, avalanche velocities and impact pressures on objects (buildings, infrastructures, etc.).

In principle, three different types of avalanches occur: Dry snow dense flow avalanches; Wet snow plug flow avalanches; and Powder snow avalanches[101] [102] [103]. Their occurrence depends on the topography, the morphology of the terrain, and on the physical characteristics of the snow cover, which over mountainous terrain change both seasonally and with respect to altitude and climatic situation[104].

Since avalanches are confined to high altitude areas, only restricted areas, mainly in the northeast of the country, are significantly affected by this hazard. For instance, the existing line between Kabul and Khwaja Alwa, and the future lines north of Kabul are crossing high risk areas.

7.3.5 Earthquakes

Damages to transmission lines and substation components as a consequence of earthquakes have been observed during many earthquakes worldwide [105]. A few cases of damages to dams have also been recorded worldwide[106]. The earthquake risk analysis produces estimates of earthquake hazard and its uncertainties during the entire process of development of the earthquake: from its onset at the source, to the production of waves traveling through the earth, to the site on the earth's surface where the impacts need to be assessed. The characteristics of the earth movement at each site depend on the duration, amplitude and frequency of the ground motion, the distance from the fault, the rupture length of the fault, and the local site conditions.

The seismic hazard is estimated using a probabilistic approach to calculate the probability of exceeding any level of ground shaking from all potential seismic sources in the area. All possible single events are analyzed to produce a probabilistic exceedance of a certain shaking. The ground motion at given locations is estimated using a ground motion prediction equation, which is based

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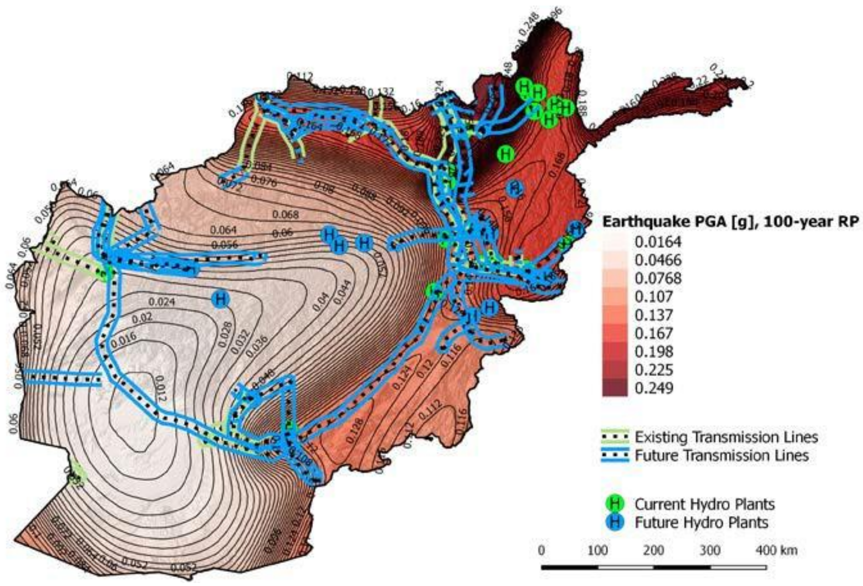
[101] Ammann, W. (2003). *Snow, avalanches, protection measures. Lecture Notes.* ETH Zürich.
[102] Kern, M. A., Bartelt, P., Sovilla, B., & Buser, O. (2009). Measured shear rates in large dry and wet snow avalanches. *J. Glaciol., 55*, 327-338
[103] Sovilla, B., Schaer, M., Kern, M., & Bartelt, P. (2008). Impact pressures and flow regimes in dense snow avalanches observed at Vallée de la Sionne test site. *J. Geophys. Res., 113*(F01010), 1-14
[104] McClung, D., & Schaerer, P. (2006). *The Avalanche Handbook.* The Mountaineers Books
[105] Fujisaki, E., Takhirov, S., Xie, Q., & Mosalam, K. (2014). Seismic Vulnerability of Power Supply: Lessons Learned from Recent Earthquakes and Future Horizons of Research. *Proceedings of the 9th International Conference on Structural Dynamics, EURODYN 2014* (pp. 345-350). Porto, Portugal, 30 June - 2 July 2014: A. Cunha, E. Caetano, P. Ribeiro, G. Müller (eds.
[106] USCOLD. (2000). *Observed Performance of Dams During Earthquakes. Volume II.* United States Committee on Large Dams. Retrieved from http://www.ussdams.org/wp- content/uploads/2016/05/ObservedPerformanceII_V2.pdf

on the source model (zones and faults) and on historic earthquake data. Hazard is quantified as the earthquake peak ground acceleration (PGA) for a given return period. Approximate scales that establish a relationship between PGA and the Modified Mercalli Intensity have been developed[107], and have been used to assess perceived shaking and potential damage in reference to specific earthquakes[108]. In general, damages are caused by PGA exceeding the threshold of 0.1*g* [109], although in some cases damages to structures have been observed for PGA as low as 0.05*g* [110].

Figure 7.7 shows the PGA contour lines measured in units of gravity acceleration, $g = 9.81\ ms^{-2}$, for a 100-year return period (RP), along the paths of the existing and future transmission lines. The figure shows that the areas with the highest probability of earthquakes are located in the north east of the country, in the regions of Takhar, Badakhshan, Baghlan, and Kunduz. In this area, the PGA for a 100-year RP is above 0.2*g*, with a peak above 0.25*g* located at the northern edge of the Takhar region. The existing and future lines connecting Kunduz are the most exposed, including the line between Kunduz and Geran (about 67 km), Asqalan and Sangtuda (about 63 km), Kunduz and Chan Ab (about 140 km), Toluquan and Falzabad (about 175 km), Qala-e-Zal and Dasht-e-Archi.

[107] Wald, D. J., Quitoriano, V., Heaton, T. H., & Kanamori, H. (1999). Relationships between Peak Ground Acceleration, Peak Ground Velocity, and Modified Mercalli Intensity in California. *Earthquake Spectra, 15*(3), 557-564.
[108] Worden, C., & Wald, D. (2016). *ShakeMap Manual Online: technical manual, user's guide, and software guide.* U. S. Geological Survey. doi:10.5066/F7D21VPQ
[109] ESEG. (2011). *Encyclopedia of Solid Earth Geophysics.* Encyclopedia of Earth Sciences Series. Edited by H.K. Gupta. Springer
[110] Bolt, B. A., & Abrahamson, N. A. (2003). *Estimation of Strong Seismic Ground Motions, International Handbook of Earthquake and Engineering Seismology.* Academic Press.

Figure 7.7 Distribution of earthquake peak ground acceleration (PGA) contour lines measured in units of g=9.81ms^{-2} for a 100-year return period (RP), along with existing and future hydro plants and transmission lines.



7.4 Disaster Risk Management

Every type of infrastructure is planned and designed taking into consideration the impact of long term climate change and natural hazards. Clearly, an evident difficulty is the uncertainty concerning the spatial and temporal distribution of natural impacts during the projected lifetime of the infrastructure. Traditional engineering methods account for future uncertainties based on statistical methods, which are typically based on empirical probability distributions of past events. However, because of the time scale of climate change, and the introduction of additional uncertainties and potential changes in user demand, urbanization, land use, resource availability, and economic development in general, the statistical approach does not provide reliable results. The requirement that the infrastructure will keep meeting future needs cannot be satisfied based on deterministic projections.

Rather, adaptable designs and plans should be defined by the range of possible future scenarios, along with probabilistic risk hazard assessments. In this context, projects should include at the offset the requirements – and budget – for future monitoring, maintenance, and adaptation. Flexible design is also required to account for the secondary impacts of climate change, such as changes in demographic, land cover, land use, and resource availability. Furthermore, adaptability of infrastructure design cannot be implemented without a parallel effort to continuously adapt relevant regulations, standards, zoning laws, which are often the result of delicate balances and negotiations.

7.4.1 The Observational Method

In order to address decision makers needs in conditions of deep uncertainties about the future climate change or the likelihood of natural disasters, more flexible approaches are necessary such as the risk management tool known as observational method, which allows modifications to be implemented during the phases of design, construction, and after construction[111]. This approach would consist in identifying the most probable climate and hazard conditions, and devise in advance the necessary modifications or actions to be implemented for all possible deviations from the assumed climate conditions. The obvious advantage of such a method is a more economic and effective design, while still ensuring safety under the least favorable conditions. The observational method is one of the tools recommended by Eurocode 7 (2004), which is one of the European standards for structural design within the European Union developed by the European Committee for Standardization, as a support to geotechnical design.

The cyclic monitoring and risk assessment process prescribed by the observational method can be represented using a traditional risk management framework. For example, Figure 7.8 shows a suitable risk management framework to plan, design and implement projects under future uncertainties, developed adapting the risk management process proposed by the International Standards Organization[112].

Consistent with an observational method approach, the benefit-cost analysis follows the incremental development of the project, with cost analysis being developed for every alternative feature. In general, low- regret strategies are recommended, such as those resulting from the employment of a robust decision making methodology[113]. A robust design approach consists essentially in proposing a set of alternatives that are likely to be acceptable over a broad range of scenarios, minimizing regret.

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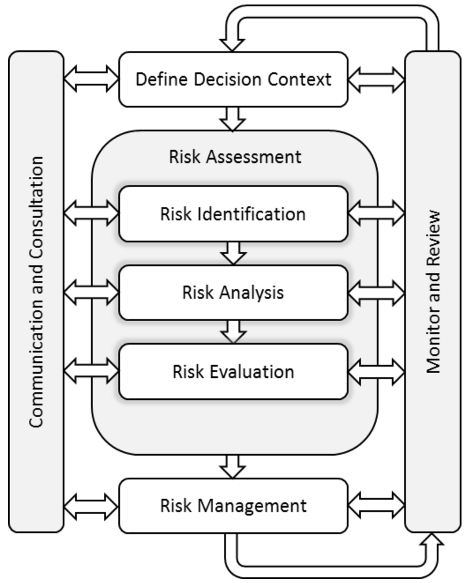
[111] Peck, R. (1969). Advantages and limitations of the observational method in applied soil mechanics. *Geotechnique, 19*(2), 171–187.

[112] ISO. (2009). *ISO 310000:2009, Risk management – Principles and guidelines.* Geneva, Switzerland International Organization for Standardization

[113] IPCC. (2001). *Climate Change 2001: Mitigation, Contribution of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change.* (B. Metz, O. Davidson, R. Swart, & J. Pan, Eds.) Cambridge University Press

Figure 7.8 The risk management framework proposed by the International Standards Organization



7.4.2 Adaptation Strategy

Along with the implementation of a risk management framework, resilience to climate and natural hazards requires the formulation and implementation of an adaptation strategy. Future climate and natural risks, which are incorporated into infrastructure planning and design, need to be incorporated into the policy- making process as well. The UNDP recommends an adaptation policy framework (APF) as a roadmap to guide the adaptation policy-making processes [114]. The APF process consists of five components: i) Scoping and designing an adaptation project (ensuring integration into the national policy planning and development process); ii) Assessing current vulnerability; iii) Assessing future climate risks (development of scenarios); iv) Formulating an adaptation strategy (integration of adaptation policies into a cohesive strategy); and v) Continuing the adaptation process (monitor and evaluation).

7.5 Conclusions

According to the Ministry of Energy and Water, Renewal Energy Department (MEW-RED, 2016), “more than 60% of the people across the country live in dark homes, without access to reliable form of electricity with no connections to power grids or large-scale energy. Many live in remote rural village communities.” The sources of energy for most people are burning of wood and diesel generators at high costs for fuel, which contribute to air pollution and deforestation. Many people in rural areas rely on kerosene and dried cakes of animal dung.

[114] UNDP. (2004). *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures.* (B. Lim, & E. Spanger-Siegfried, Eds.) Cambridge University Press

As was noted earlier in this paper, Afghanistan does not have a single electric grid, but several island grids, which are not synchronized or connected to each other. A number of projects are being planned or implemented to provide access to non- grid electricity from local sources such as micro hydro power from turbines in local streams, solar panels and wind turbines. The Special Inspector General for Afghanistan Reconstruction[115] reports that topography and demographics hinder the expansion of transmission and distribution in Afghanistan, citing research from Kansas State University: "Importing more electricity would not help the country's predicament in rural areas, where the infrastructure does not exist […]. Expanding the power grid to mountainous rural areas is nearly impossible[116]".

A paper of the U.S. Department of Defense[117] concludes that extending the central grid to increase rural electricity access can become cost prohibitive (up to $400,000 per kilometer), and proposes a 'Distributed Renewable Energy' model to achieve economic viability, sustainability, and scalability through "a phased approach to implementing distributed renewable energy infrastructure in rural Afghanistan".

The electric grid is a major source of vulnerability in the energy system. Models of centralized generation and long-distance transmission are coming into question in the wake of several recent natural disasters which created widespread power outage, illustrating the current fragility of the system, derived from its susceptibility to climate and natural hazards. A possible adaptation measure for the energy system is represented by transitioning toward more resilient power generation and transmission models, such as a decentralized power system, and the integration of distributed generation from renewable sources with intelligent grid systems.

The limited reach of regional grids in Afghanistan implies that smaller scale off-grid renewable energy technologies such as small hydro and wind solar PV can be major factors in a development program by providing access to energy, particularly in rural areas.

With climate projections highlighting the vulnerability of water resources, identification of sites for new HPP is critical, because of Afghanistan's heavy reliance on hydro power within the domestic power mix. Future potential HPP sites may not be suitable for hydropower, and current HPP may be losing productivity, partly because of increased use of water for irrigation upstream. Most micro HPP are of the run-of-river type and do not include a water reservoir, making them

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[115] SIGAR. (2016). *Quarterly Report to the United States Congress.* 2530 Crystal Dr. Arlington, VA:Special Inspector General for Afghanistan Reconstruction.
[116] Davis, T., Tammen, G., & Tidball, a. J. (2016, 5). Brightening Afghanistan. *Seek: Research Magazine for Kansas State University*, *3*(1), p. 2
[117] Haag, K. (2012). Department of Defense creates 'Distributed Renewable Energy' model to uplift rural communities in Afghanistan. *World Renewable Energy Forum* (p. 7). Denver, CO: American Solar Energy Society

more vulnerable to variations of river flow. For single turbine micro HPP the power output decreases disproportionately with water level drop, because the flow cannot be redirected to fewer turbines so as to preserve their efficiency.

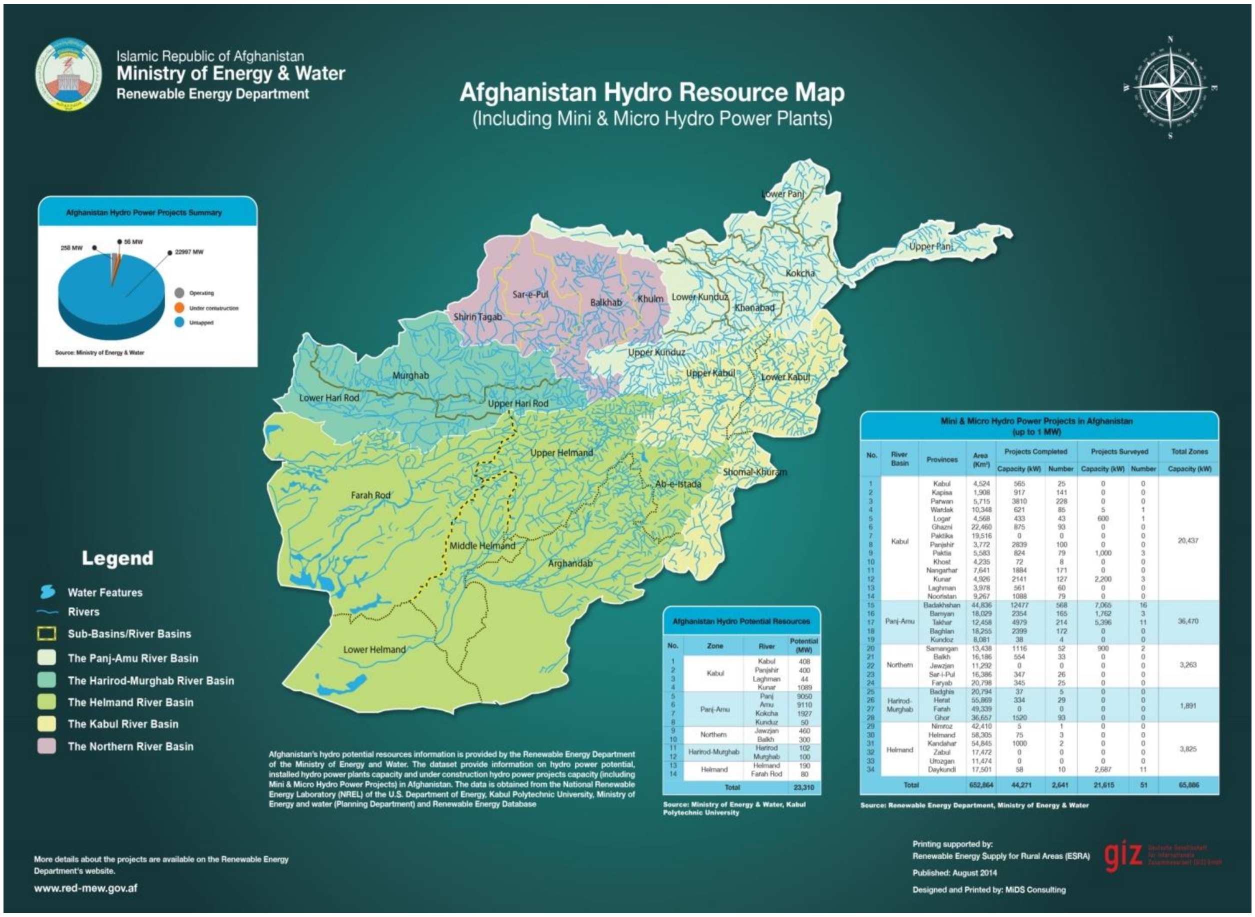
Research on climate change impacts on wind energy conducted in specific geographic regions indicate a small or negligible effect of climate change on wind energy output. The impact of climate change on solar PV and CSP output is generally small, and on a planetary scale depends on the source location. A recent study from Crook, Jones, Forstera, & Crook[118] calculated the global percent change in PV and CSP output in 2080, relative to a baseline of the 1980-1999 mean. The simulation results indicate that PV increases or decreases by a few percent, depending on geographic location. CSP is more sensitive to climate change with larger percent changes (e.g., more than 10% in Europe), but still very location dependent.

Increasing diesel prices contribute to consider renewable resources a competitive solution, because of their consistently declining costs and increasing availability. Resilience to climate change of solar PV installations, along with their penetration potential in off-grid rural areas, and Afghanistan elevated solar radiation, give solar PV systems a competitive advantage.

[118] Crook, J. A., Jones, L. A., Forstera, P. M., & Crook, R. (2011). Climate change impacts on future photovoltaic and concentrated solar power energy output. *Energy Environ. Sci.*, *4*, 3101-3109

Annex A: MAPS

Figure A-1 Afghanistan Hydro Resources



Afghanistan Hydro Potential Resources

No.	Zone	River	Potential (MW)
1	Kabul	Kabul	408
2		Panjshir	400
3		Laghman	44
4		Kunar	1089
5	Panj-Amu	Panj	9050
6		Amu	9110
7		Kokcha	1927
8		Kunduz	50
9	Northern	Jawzjan	460
10		Balkh	300
11	Harirod-Murghab	Harirod	102
12		Murghab	100
13	Helmand	Helmand	190
14		Farah Rod	80
	Total		23,310

Source: Ministry of Energy & Water, Kabul Polytechnic University

Mini & Micro Hydro Power Projects in Afghanistan (up to 1 MW)

No.	River Basin	Provinces	Area (Km²)	Projects Completed		Projects Surveyed		Total Zones
				Capacity (kW)	Number	Capacity (kW)	Number	Capacity (kW)
1	Kabul	Kabul	4,524	565	25	0	0	20,437
2		Kapisa	1,908	917	141	0	0	
3		Parwan	5,715	3810	228	0	0	
4		Wardak	10,348	621	85	5	1	
5		Logar	4,568	433	43	600	1	
6		Ghazni	22,460	875	93	0	0	
7		Paktika	19,516	0	0	0	0	
8		Panjshir	3,772	2839	100	0	0	
9		Paktia	5,583	824	79	1,000	3	
10		Khost	4,235	72	8	0	0	
11		Nangarhar	7,641	1884	171	0	0	
12		Kunar	4,926	2141	127	2,200	3	
13		Laghman	3,978	561	60	0	0	
14		Nooristan	9,267	1088	79	0	0	
15	Panj-Amu	Badakhshan	44,836	12477	568	7,065	16	36,470
16		Bamyan	18,029	2354	165	1,762	3	
17		Takhar	12,458	4979	214	5,396	11	
18		Baghlan	18,255	2399	172	0	0	
19		Kundoz	8,081	38	4	0	0	
20	Northern	Samangan	13,438	1116	52	900	2	3,263
21		Balkh	16,186	554	33	0	0	
22		Jawzjan	11,292	0	0	0	0	
23		Sar-i-Pul	16,386	347	26	0	0	
24		Faryab	20,798	345	25	0	0	
25	Harirod-Murghab	Badghis	20,794	37	5	0	0	1,891
26		Herat	55,869	334	29	0	0	
27		Farah	49,339	0	0	0	0	
28		Ghor	36,657	1520	93	0	0	
29	Helmand	Nimroz	42,410	5	1	0	0	3,825
30		Helmand	58,305	75	3	0	0	
31		Kandahar	54,845	1000	2	0	0	
32		Zabul	17,472	0	0	0	0	
33		Urozgan	11,474	0	0	0	0	
34		Daykundi	17,501	58	10	2,687	11	
	Total		652,864	44,271	2,641	21,615	51	65,886

Source: Renewable Energy Department, Ministry of Energy & Water

Figure A-2 Afghanistan Solar Resources

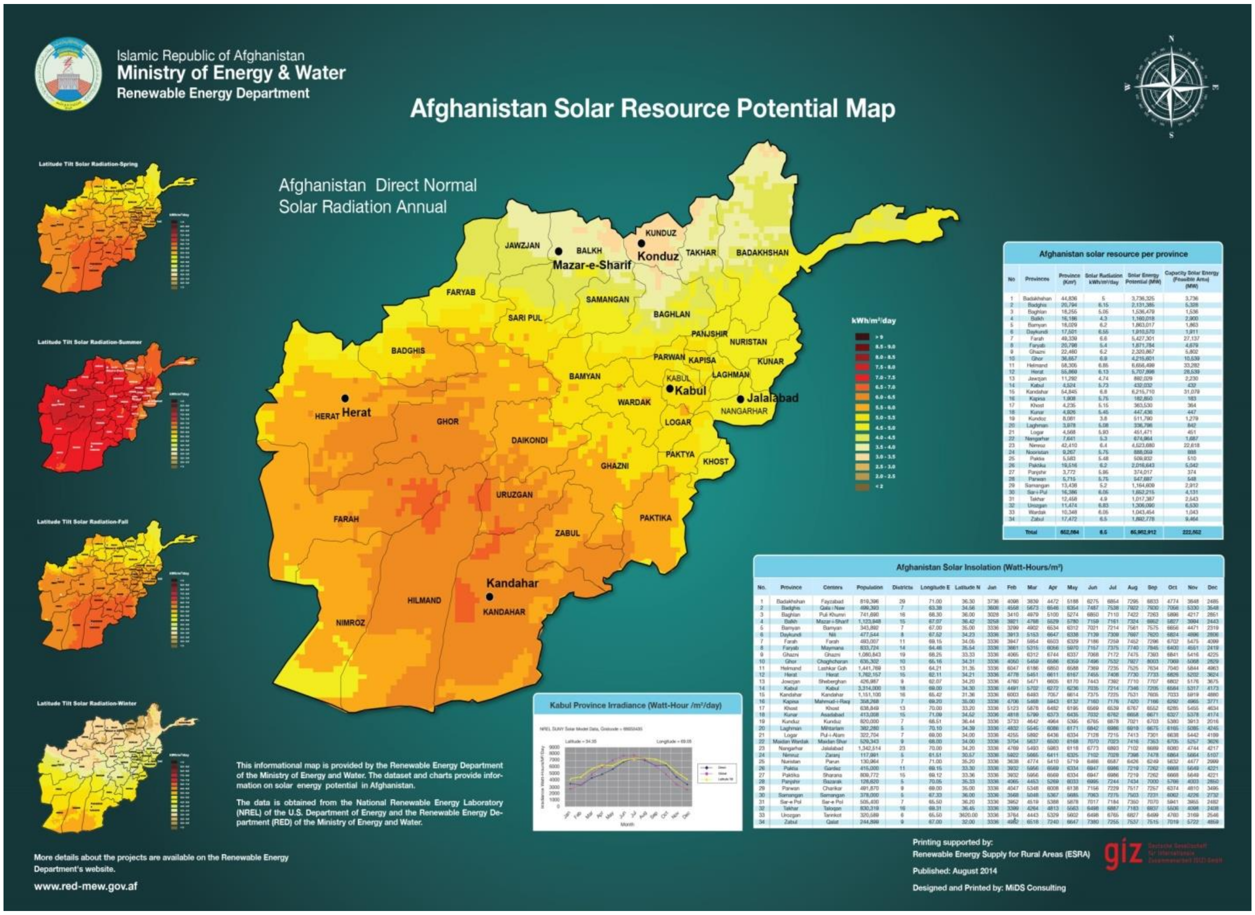


Figure A-3 Afghanistan Solar Resources, PV Out

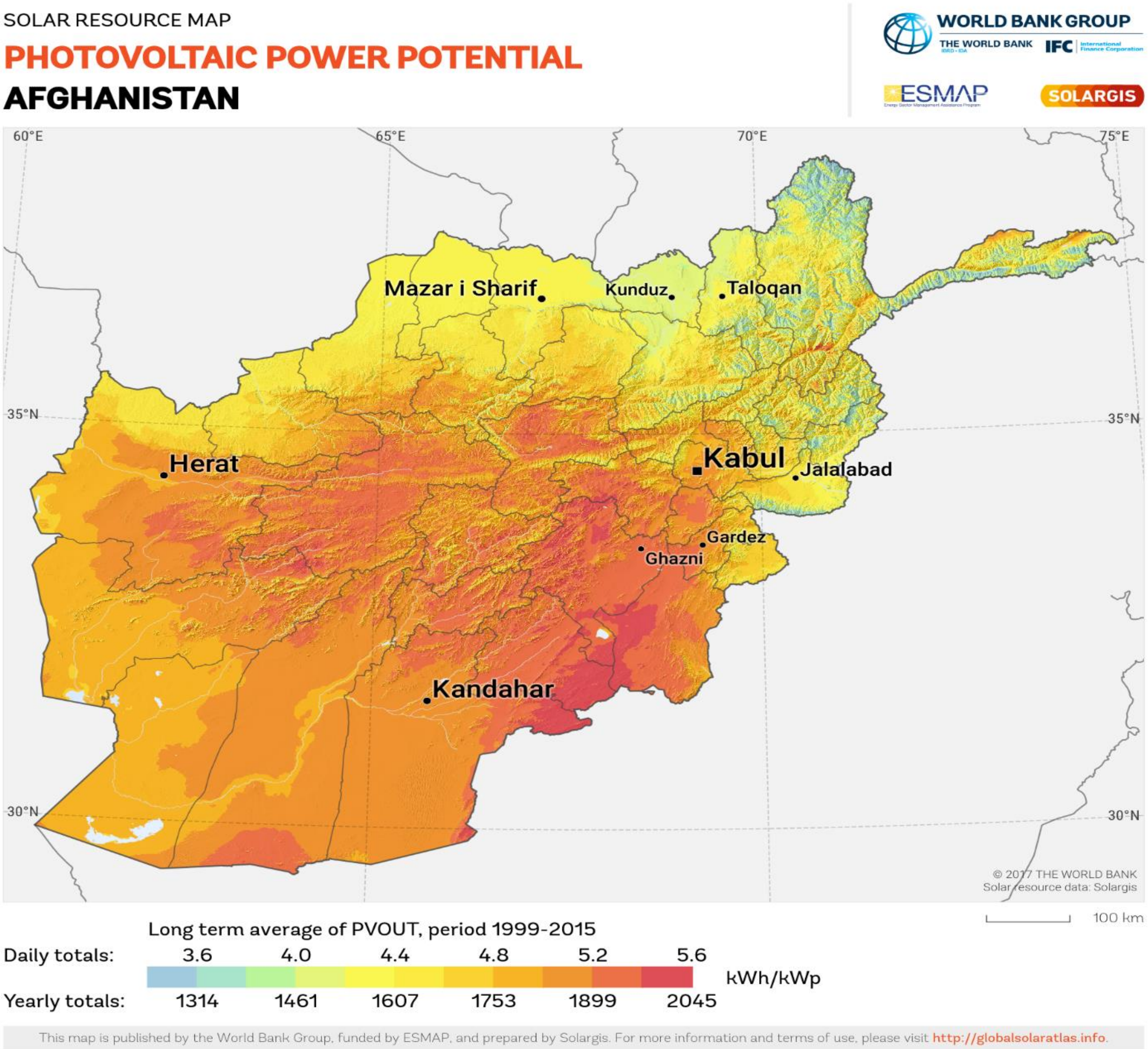


Figure A-4 Afghanistan Solar Resources, GHI

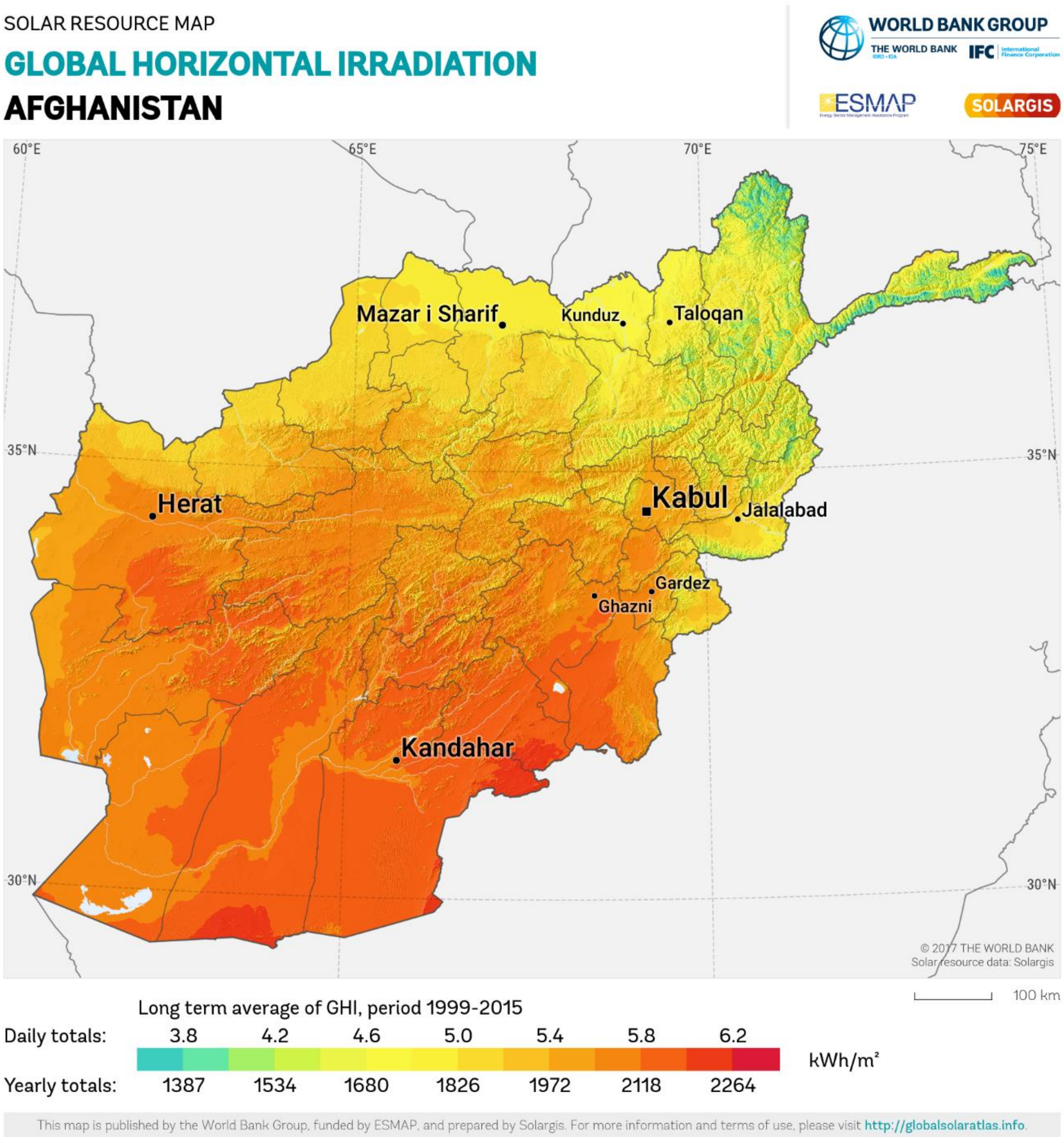


Figure A-5 Afghanistan Wind Resources

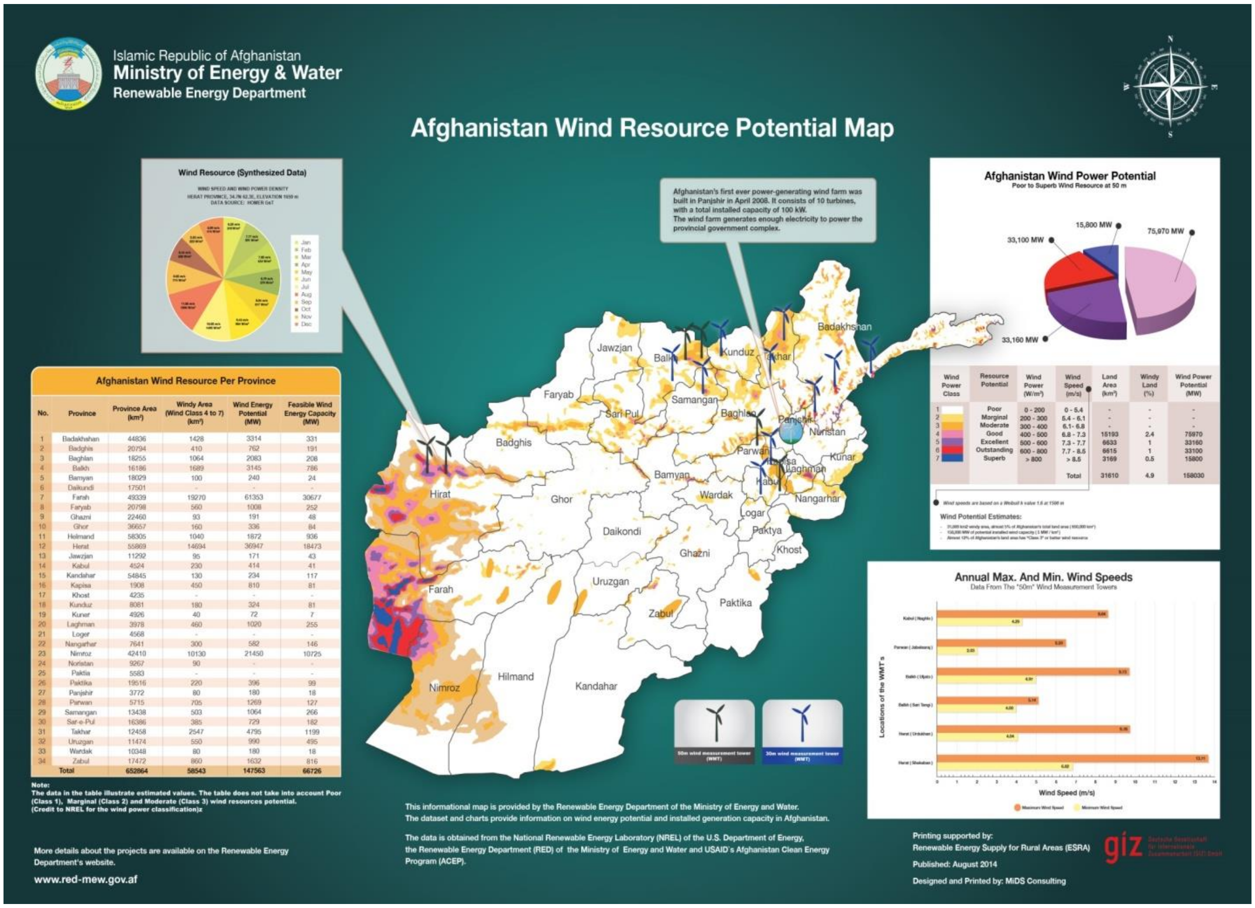


Figure A-6 Afghanistan Wind Resources, Power Density

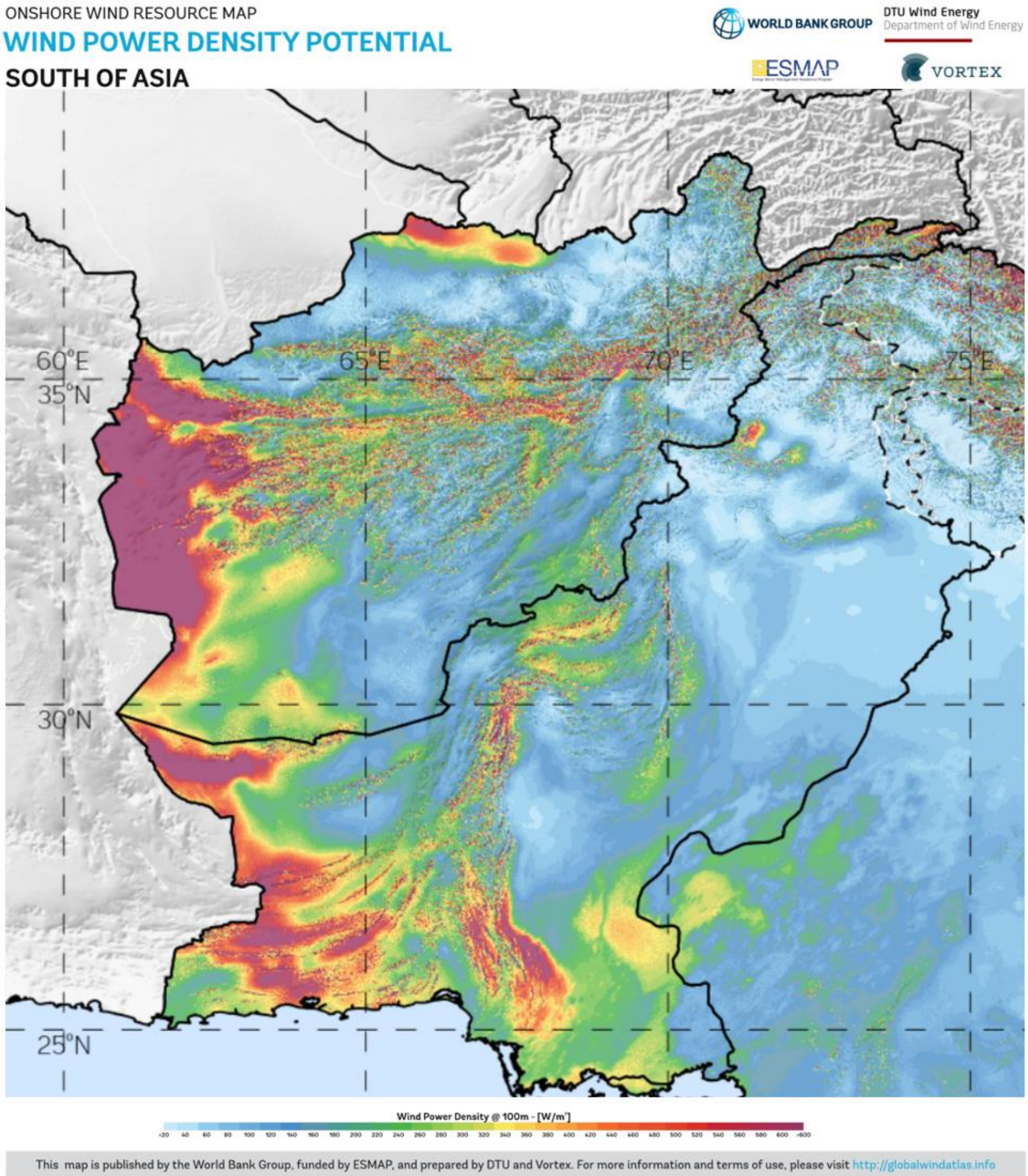


Figure A-7 Afghanistan Wind Resources, Wind Speed

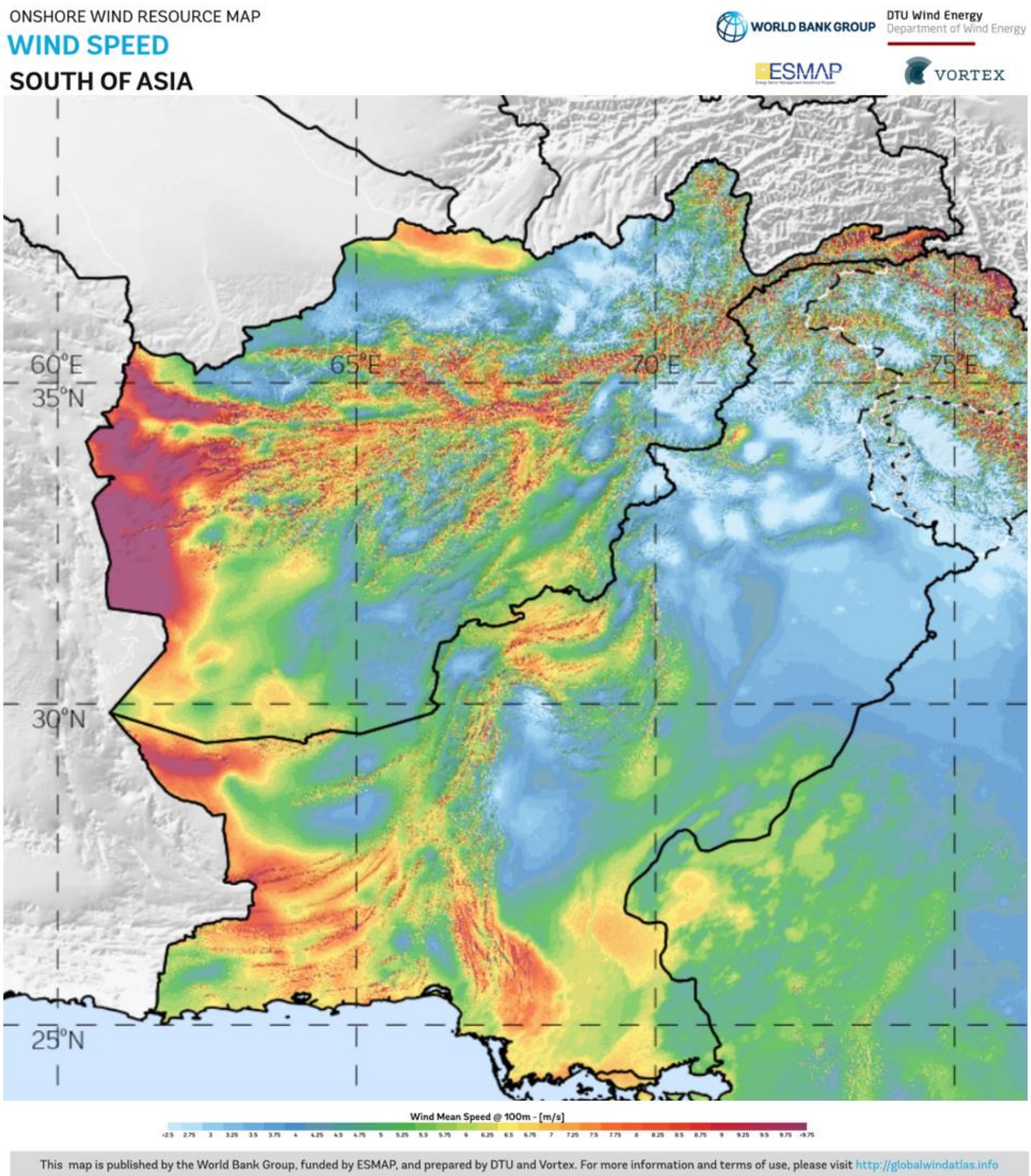


Figure A-8 Afghanistan Biomass Resources