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Potential and utilization of renewable energy sources in Afghanistan

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Abstract
Energy access and energy security are two key requisites for the socio-economic growth of Afghanistan societies. Renewable energy resource with their enormous potential can successfully be harnessed to meet these two requirements. The development of renewable energy sector is thus a priority area for the Government of Afghanistan and all its supporting partners. An important pillar for the renewable energy sector development is the engagement of the private sector and financing institutions. The Government's renewable energy roadmap is designed to increase the supply of energy from domestic resources; improve energy supply to load centers, provincial capitals, and rural population; and increase the capacity within the Government to plan and implement renewable energy projects. It includes prioritization of RE technologies and projects, designing appropriate business models for their implementation and identifying enablers for market development.

Keywords: Renewable energy; Sustainable development: Global climate change; Afghanistan

1. Introduction

Afghanistan is a landlocked country located at the crossroads of Central and South Asia [1]. It is bordered by Pakistan to the east and south, Iran to the west, Turkmenistan and Uzbekistan to the north, and Tajikistan and China to the northeast. Occupying 652,864 km^2 of land, the country is predominately mountainous with plains in the north and the southwest that are separated by the Hindu Kush mountain range [2]. As of 2020, its population is 34.4 million. Kabul is the country's largest city and its capital [3]. Currently, Afghanistan is ranked as one of the least developed countries in the world and has high levels of poverty and child malnutrition. Its economy is the world's 96th largest, with a gross domestic product (GDP) of $74 billion by purchasing power parity; the country fares much worse in terms of per-capita GDP, ranking 169th out of 186 countries as of 2018. In the current situation (2021), over 70% of the population lived in poverty, and unemployment stood at 81% of the labor force. The Afghan average literacy rate is 55% countrywide, only 40% of female Afghans are literate [4-10].

2. Energy and electricity in Afghanistan

Afghanistan has different kinds of energy reserves like coal, uranium, niobium, oil and gas, and rivers, most of which are intact. Before explaining these sources, it is better to know why these sources are not used yet. There are some key issues could represent risks or barriers to the full development of the sector [10]. Commercial risks relate to uncertainties about the commitment and creditworthiness of the off-taker, 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. There is also a lack of private insurance against commercial risks [1-17].

Gaps in the legal and regulatory framework also represent risks to developers. 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

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mini-grid projects as opposed to a utility-scale initiative [11]. 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 [12].

Afghanistan’s renewable energy 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, and municipal solid waste is also plentiful. While it is now used directly for heating and cooking, it could also be exploited to generate electricity. Afghanistan's water, wind, solar and biomass resources have a capacity of 398,125 MW. Among these, the potential capacity for generating hydroelectric power is 23,310 MW; wind power 147,563 MW, solar electricity 222,852 MW, and electricity generation from biomass sources is about 4,400 MW [10, 12].

According to the Ministry of Energy and Water, Renewal Energy Department (MEW-RED), more than 60% of the people across the country live in dark homes, without access to a 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 [15-17].

The existing power supply system in Afghanistan is deficient in many respects including geographic coverage, flexibility and adequacy and cost of domestic supply. While 86% of households reported having some kind of access to electricity in the 2018 Living Conditions Survey (ALCS), only 29.7% 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 [11].

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 2020, the number of household connections to the grid increased by 68%. Households dominate the customer base, representing almost 93% of total connections, while commercial customers represent just under 7% and government agencies less than 1%. 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%. Peak demand was forecast to increase from approximately 760 MW at the beginning of the forecast period (2020) to a projected 3,502 MW in 2032 [9-12].

3. Renewable energy potential and utilization

3.1. Introduction

Afghanistan is facing many economic and political challenges 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 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% of forecast electricity demand (350-500 MW) through RE by 2032 [1, 3, 5, 9].

3.2. Renewable energy 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 [4]. Total hydroelectric capacity (recoverable) is estimated at 23,000 MW, of which 87% (20,000 MW) is in the north-east on the Amu Darya, Panj and Kokcha Rivers. A further 8% (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 [5-7].

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/m^2.day, electricity generation is technically feasible. 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 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.

3.3. Integrating renewable energy into the supply plan

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. Figure 1 shows development of renewable energy roadmap for Afganistan.

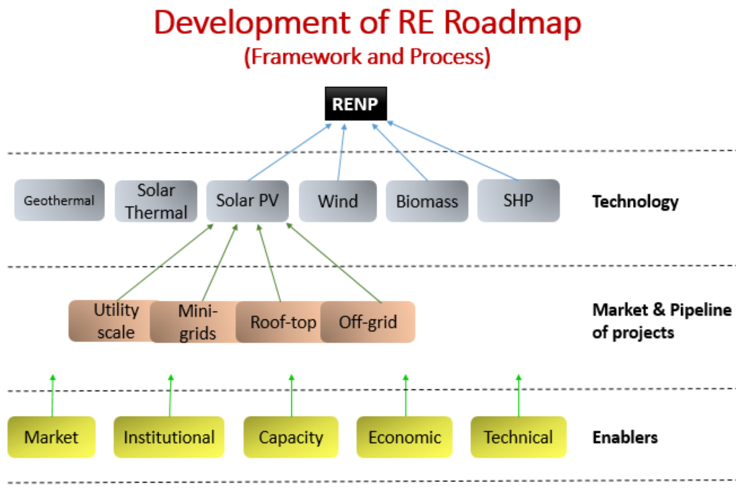

Figure 1. Development of renewable energy roadmap for Afganistan.

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. The study determined that large areas of the south and south-west showed potential to supply upwards of 20,000 MW 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 MW per year at average costs that ranged from a low of US$0.097/kWh to a high of S$0.137/kWh (excluding interconnection to the road and transmission system which would add in the order of 20 percent to these costs). The wind potential identified areas in the south, southwest and northwest with potential to supply wind energy. The areas of highest productivity were concentrated in the western parts of Herat and Farah provinces with potential outputs of 30,000-50,000 MW per year per spatial unit. The overall annual output capacity of the areas identified as having potential to accommodate wind developments averaged 21,285 MW 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/kWh, although costs in some of the areas that had technical potential averaged as high as US$0.197/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 /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 standalone, 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% of the population.

The Government of Afghanistan (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.

3.4. Hydropower resources

With its mountainous terrain and extensive river system, Afghanistan is estimated to have a recoverable hydro potential of more than 23,000 MW. The vast majority of this potential (roughly 20,000 MW) is located in the northeast 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 Jowzjan regions in the northwest have approximately 800 MW of potential, while the remaining resources (about 500 MW) lie in the west-central part of the country [5, 6, 10].

Table 2. Existing hydropower plants

Name	River	Capacity (MW)
Naghlu	Kabil	100
Sarobi	Kabil	22
Mahipar	Kabil	66
Darunta	Kabil	12
Kajaki	Helmand	34
Total Country		250

3.5. Solar resources

Most of Afghanistan lies between a latitude of 30° and 38° north and 60° to 72° 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. The total estimated national capacity based on solar radiation and the feasible area is 222,000 MW [5, 6].

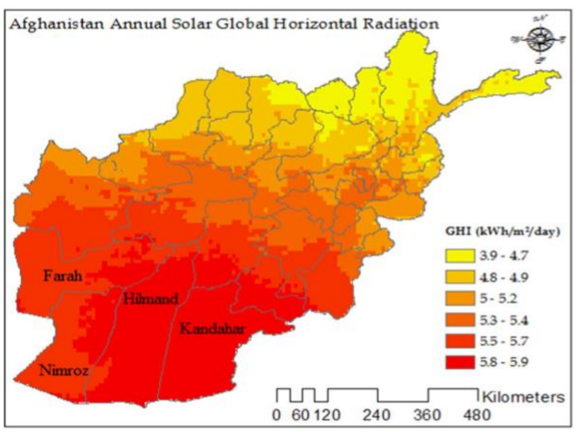

Fig. 2. Annual Global Horizontal Radiation [10].

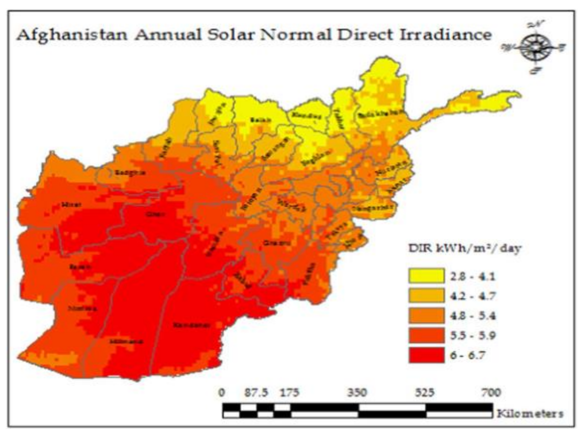

Fig. 3. Annual Solar Direct Irradiance [10].

3.6. Wind resources

Afghanistan's wind resources are also substantial, but highly localized. 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 the 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 [5, 6, 10]

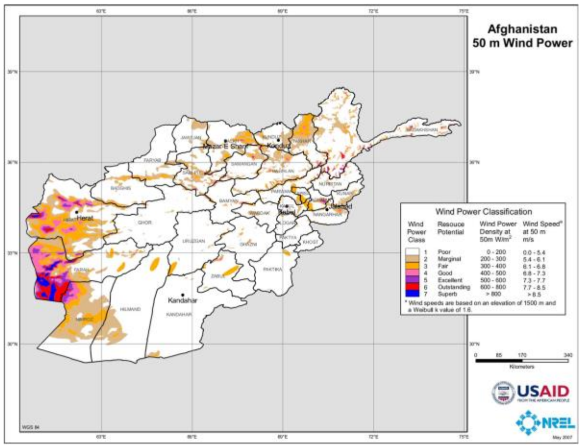

Figure 4. Afghanistan 50 m Wind Power Map [10].

3.7. 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 [5, 6].

3.8. Biomass resources

Biomass is already used extensively in Afghanistan for home heating and cooking. The primary resources available are crop residues, animal manure, firewood, and municipal waste. According to the ALCS, 74% of all households and 90% of rural households relied on biomass as their primary fuel for cooking, while 82% of households and 90% of rural households used it 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 [5, 6].

4. Conclusions

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. 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 microand 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.

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