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A brief overview of Kabul city electrification

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ABSTRACT

Kabul faces challenges with fulfilling energy demand using a problematic conventional electrical grid. Its transportation system is disorganized, and ICT infrastructure is limited as the population growth rate is increasing. Kabul should determine feasible and efficient plans to make its energy system more sustainable and smart. Afghanistan energy utility Da Afghanistan Breshna Sherkat- (DABS) provided electricity demand, consumption, import, amount of thermal electricity and thermal generation data for this research. The data about ICT infrastructure has been extracted from SIGAR reports and transportation data has been obtained from the transportation department in Kabul. Population data come from Afghanistan Central Statistics Organization (CSO). In summary, usage of solar, wind, hydro and biomass energies and electricity by transmission lines are the most feasible and efficient ways to provide the needed electricity. A smart grid can be established through smart metering and energy efficiency as well as some measurement programs. Improved ICT infrastructure can benefit citizens with lower prices, better service, and increased competition. Finally, transportation systems options like electric vehicle (EV), public transportation, and ATMS are recommended.

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1. Introduction

A smart energy system formally consists of "new technologies and infrastructure that create new forms of flexibility, primarily in the 'conversion' stage of energy system" and is built around three grid infrastructures [1]:

– Smart electricity grids connect flexible electricity demand such as heat pump electric vehicles to intermittent renewable sources such as solar and wind.
– Smart thermal grids connect the electricity and heating sectors, using thermal storage for additional flexibility and recycling heat losses in the energy system.
– Smart gas grids connect the electricity, heating and transportation sectors using gas storage for additional flexibility. If the gas can be refined to liquid fuel, then liquid fuel storage can also be utilized.

Sustainability is defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs."

Energy is one of the most important foundations in growth of a city. Kabul's demand is 620 MW [2], but the government can only provide 363.5 MW, and its conventional electrical system is associated with problems like limited interaction, non- or one-way communication, limited power flow control, and cascading outages.

Kabul's transportation system is disorganized, and most cars are antiquated and generate hazardous gases which damage the environment. The ICT infrastructure of Afghanistan has substantially grown from almost nonexistent in 2002 to one of Afghanistan's most successful economic sectors today. However, customers complain that the service is too slow and the price is too high.

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Table 1: List of planned solar generation projects in Kabul [2].

No	Power Plant Name	Generation type	Total capacity(MW)	Current status	Remarks
1	Naghlo Solar Park (I)	Solar	20	Under evaluation to Be submitted to NPA &ADB	Funded by ADB
2	Naghlo Solar Park (II)		20	Under Feasibility Study	Funded by WB
3	Naghlo Solar Park (III)		10	Under Feasibility Study	Funded by ADB
4	Kabul 400MW Solar Package		400	Planned	MEW/PPP
5	Naghlo solar Park		50	Planned	MOF(PPP) MEW,DABS
6	Kabul Miili (Pul-e-Charkhi) Solar Project		30	Planned	MOF(PPP) MEW,DABS
7	Naghlo solar Park (II)		10	Under Feasibility Study	DABS

2. Proposed solutions

2.1. Sustainable Energy

Kabul's population is estimated to double from 2018 to 2032. According to the Afghanistan Power Sector Master Plan, to meet the anticipated peak demand in Kabul of 1215.7MW [3], sustainable energy (solar, wind, and hydroelectric) and distributed generation projects have been suggested.

1- Solar Energy: As Kabul has abundant solar potential, utilizing solar energy as distributed power for the whole city is highly recommended. Though large-scale PV farms are not practical in a dense capital city, rooftop solar will be an excellent alternative. According to the Sasaki design framework, three types of rooftop solar solutions are suggested for Kabul.

– Rooftop solarwater heater is very common in many cities all over the world. A preliminary goal to install solar water heaters in 5,000 homes across Kabul was suggested [4].

– Rooftop PV for Government: DABS has announced an initiative to build a 15MW solar rooftop PV on government buildings in Kabul such as the Government Administrative Complex being planned to meet 545MW of anticipated demand [2].

– Rooftop PV for Industrial Parcels: Industrial areas are another ideal place for rooftop PV, as factories usually have huge flat roofs where a great number of solar panels can be installed to satisfy demand for a large amount of electricity [4].

2- Wind Energy: Kabul experiences prevailing winds from the northwest direction with average speeds between 3.1 and 5.4 m/s [4]. It is estimated that Kabul has 41 MW wind capacity [5]. Based on the geography and the strategic development areas in Kabul, two sites are considered ideal for wind energy development.

– Hilltop Wind Turbines: the hilltops in District 17 may be good candidates for small-scale wind energy projects [4].

– Agricultural Belt Wind Turbines 100 wind turbines can be installed in the agricultural belt of Kabul. A common wind turbine for agriculture is usually 60-100m in diameter with 80m in height, each with a capacity of 100-300 kW, to generate around 20 MW for local residents or to be put into the grid [4].

Based on the global average installation cost of utility-scale onshore wind projects (US$1,071 per kW in 2019) the predicted cost for 20MW wind energy generation in Kabul will be $21 million [6].

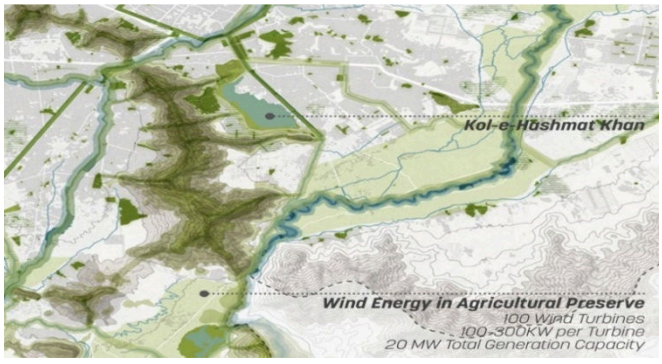

Figure 1. Map of Kol-e-Hashmat khan [4].

3- Hydro Energy: Kabul has three hydropower plants: Naghlo (total capacity of 100MW), Surobi (22MW), and Mahipar (66MW). Under construction, Surobi II should generate 180 MW to bring Kabul's total hydro-electrical generation to 368 MW [2].

4- Biomass Energy: Kabul can generate 126,884 MWh/year MSW, 69,089MWh/year Animal manure, and 465,372MWh/year Crop Residue [5]. According to the planned project of Kabul power system, 26MW of total demand will be satisfied by implementation of these projects.

Table 2: List of planned bio mass energy projects.

No	Power Plant Name	Generation type	Total capacity(MW)	Current status	Remarks
1	Biomass Projects	Biomass	20	Planned	MEW/PPP
2	Kabul Waste to Energy Biomass Project - Kabul		10	Planned	MEW

5- Transmission line: Implementation of these projects and use of 105 MW Trakhil power plants should provide 1084 MW to meet the anticipated 1215.7 MW peak demand of Kabul in 2032 [2]. The 151.7MW deficit could be met by electrical transmission from another province.

2.2. Smart metering

Smart meters are digital programmable devices that record customer consumption of electricity of energy in intervals of an hour or less and frequently report that information back to the energy supplier for monitoring and billing purposes [6].

Kabul has 88,096 traditional meters (61,058 meter analog and 27,038 is digital) [2],which are proposed to be replaced by smart meters. With the cost of one smart meter between US$ 10 –100, the cost will be approximately $5 million.

2.3. Energy efficiency program

Improving energy efficiency of buildings will reduce demand. Currently planned government buildings, hospitals and schools are ideal locations to pilot energy efficiency programs and incentives.

As shown in other cities, LED lighting in government and commercial buildings are the simplest but most effective energy-saving practice. LED light bulbs can last almost 40 times longer than traditional light bulbs and consume only 1/6 of the electricity than regular bulbs. Rooftop solar panels on the government buildings also generate electricity during the day for their direct use.

According to the Sasaki design framework, LED lighting and rooftop solar panels should be installed in government and office buildings. With an estimated 1,000 LED lighting fixtures per building, an estimated 12 GWh will be saved annually compared with traditional incandescent light bulbs. Rooftop solar panels could generate 108 GWh electricity annually [4]. If energy-efficient design standards work for government buildings, similar designs may be applied to other buildings through zoning, tax incentives, or regulations requiring efficiency.

The Sasaki design framework also suggested is the circular economy as a strategy for industrial areas. Many technologies exist to convert waste products to energy. For example, extra steam or heat from factories can be used for a hot water supply, and sludge can be digested to create biogas.

2.4. ICT infrastructure

In addition to smart metering infrastructure, a smart grid relies heavily on ICT's to handle the data from sensors, and control and management systems. A robust and reliable ICT Infrastructure should have the following benefits for citizens: lower price, better service, extensive broadcasting area, and internet access.

2.5. Transportation

Smart transportation has the promise of decreasing air pollution, noise, and traffic within the city. Four approaches have been suggested.

2.6. Public transportation system

A public transportation system in the Kabul has been proposed using electric buses at a cost of about $100,000 each. Funding for 10 cars for each of the 22 districts of Kabul would cost $22 million.

Electric vehicle: City residents can be encouraged to use electric vehicles instead of diesel and petrol cars. The cost of electric vehicles is similar to diesel/petrol cars but without problematic emissions and savings of energy and money. In Kabul, one in every ten people owns a private car, and the cost to

convert 370,577 fuel cars to electric vehicles would cost about $3 billion [7].

On-grid solar charging stations for EV: Charging electric vehicles using solar energy further reduces fossil fuel use and emissions. One solar charging station can serve 4 EVs at the same time. The cost to install five charging stations in each of the 22 Kabul districts would be around $704,000.

Advanced traffic management systems (ATMS): ATMSs use state-of-the-art sensing, communications, and data processing technologies to reduce urban traffic congestion by regulating traffic signals. Installation of an ATMSin Kabul costs approximately $32,500 per kilometer.

3. Methodology

To provide smart and sustainable energy for Kabul city, we need to review the current situation in Kabul city:

3.1. Energy

Kabul has 363.6 MW (approximately 243.5 MW from Uzbekistan, 70 MW from hydro energy and 50 MW from thermal energy) to meet 620 MW in demand, a shortage of 256.5 MW. 638,607 customers are connected to a traditional grid and its limitations [2].

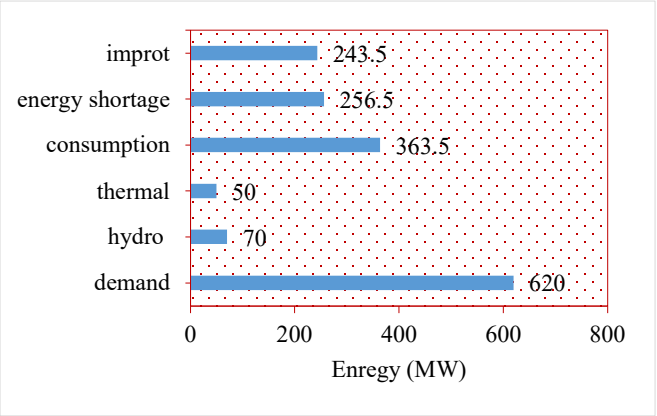

Figure 2. Energy demand and facilities of Kabul [2].

3.2. Environment

One of the world's most polluted cities, Kabul reports having 353 days of hazardous air quality due to the following reasons [8]:

- Very dusty roads
- Numerous old, polluting vehicles
- Burning plastic, used motor oil, and tires as a source of fuel
- Urban sprawl
- The bowl-shaped city landscape surrounded by the mountains which trap air pollutants and promote inversion
- Use of leaded gasoline
- Use of 2-cycle electric generators
- Generation of electricity using diesel generators
- Using coal and wood for heating and cooking
- Cutting and burning of trees, shrubs, and native bushes
- Public indifference

3.3. ICT network

The ICT infrastructure of Afghanistan has substantially grown from almost nonexistent in 2002 to one of its most successful economic sectors. The sector is primarily comprised of cellular, optical fiber cable, and satellite components [9].

Figure 3. Afghan optical fiber cable network [9].

3.4. Transportation

Transportation connects the nation and supports increasing mobility demands for travelers and cargo but at the cost of increasing motorization and congestion. There are approximately 605,517 cars and motorcycles in Kabul [7], and fuel consumption contributes to air pollution and environmental problems.

Table 3: Number of vehicles in Kabul city [7].

Kind of Cars	Number of cars	Petrol	Diesel	Annual Growth
Private	370,577	80%	20%	0.80%
Truck	82,986	5%	95%	1.83%
Bus	34,501	5%	95%	2.96%
Taxi	28,488	70%	30%	0.53%
Motorcycle	39,029	100%		6.80%
G.V	36,611	85%	15%	1.58%
T.V	13,325	95%	5%	0.21%
Foreign Cars	17,173	95%	5%	0%

3.5. Population growth

Kabul is the largest city by population in Afghanistan and the 64th-largest in the world [10]. Rapid urbanization has also led to the city being the fifth fastest-growing in the world. With a population of around 3,961,500 in 2018, Kabul has 11.339% of the total population of Afghanistan. At a growth rate of 3.79% per year, Kabul would have an estimated population in 2032 of 6,668,633.

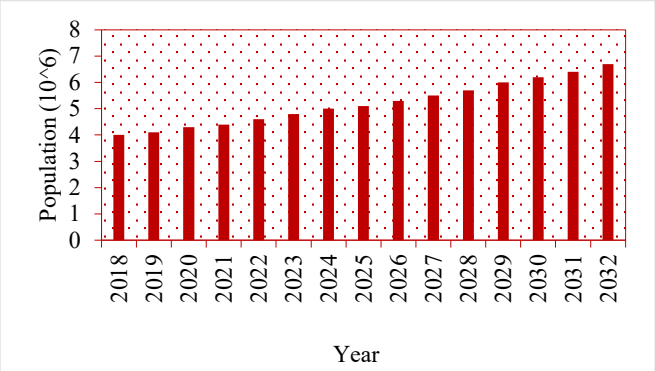

Figure 4. Estimation of Kabul city population.

4. Result and discussion

There are several challenges to implement a smart grid in Kabul. With an estimated cost of around $60.7 million, several concerns include funding, infrastructure, complexity, internet speed or connectivity, security from hackers, and accommodation of technology and electric vehicles. Implementation of a smart grid and sustainable energy can result in a smart and reliable power system, as well as other technical, environmental, and economic benefits.

By applying a smart grid, increased use of electric vehicles, and public transportation, CO_2 emissions can be reduced to 3760441.21817 tons per year, NOx reduced to 90.6179668432 tons per year, and Sox reduced to 753.1036661 ton per year. This will help Kabul arrive at three SDG goals: affordable and clean energy, sustainable cities and communities, and climate action.

5. Conclusion

Kabul is unable to maintain its energy balance as it consumes more energy than is supplied, and the current electrical grid is insufficient and problematic. These problems will worsen as its population and peak energy demand are expected to double by 2032. Among solutions to increase supply include investments in sustainable energy sources, distributed energy generation projects, smart meter installation, improved ICT infrastructure, improved transportation infrastructure, increased utilization or conversion to electric vehicles, and installation of ATMS.

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