Interdisciplinary Publication
REPA PROCEEDING SERIES

Vol 1 (1): Pages 56-69 (2020)
DOI 10.37357/1068/SODC2019.1.1.08
ISSN 2435-7308

Check for updates

International Conference on
Sustainability Outreach in Developing Countries (SODC 2019)
16-19 November 2019, Kabul, Afghanistan

Electricity and heat supply to Kabul industrial parks using renewable energy sources

Najibullah Ebrahimi, Najib Rahman Sabory, and Mohammad Abed Anwarzai
Department of Energy Engineering, Faculty of Engineering, Kabul University, Kabul, Afghanistan

Conference Proceeding
Open Access
Published

Keywords
- Industrial park
- Renewable energy
- Eco-industrial park
- Reliability
- Electrification

ABSTRACT

Industry has a leading contribution to the economic development of a nation; however, this sector needs a systematic and sustainable roadmap. From the planning point of view, there should be an IP Industrial Park (IP) with basic facilities such as water supply, sewerage system, electricity, access roads, and other entities in which, electricity and heat act as the key resources driving the IPIPs. Kabul has three IPIPs, Pul-e-Charkhi, Arghandi, and Bagrami, and their total electrical demand is 180 MW (Kabul IPs utilize an average of 8 hours a day with the total of 1440 MWh electric energy consumption). Da Afghanistan Breshna Shirkat (DABS) provides only 100 MW out of 180 MW demand. Therefore, industries fulfil their power shortage relying on fossil fuels. Kabul IPs consume 141.86 toes of fossil fuel for thermal necessity and power shortages. This fossil fuel creates environmental issues and pollution into the air. According to the Afghanistan Meteorology Organization (AMO), IPs are responsible for 30% of greenhouse gases (GHGs) emissions in Kabul city. One of the primary and best ways to solve this problem is the usage of renewable energy sources such as solar, wind, hydro, and geothermal energy. Kabul IPIPs pays $73.01 million annually, and the total cost of building the hybrid renewable plant of a concentrating solar panel (CSP) and Solar PV is estimated $545.36 million. The payback time is calculated as 7.5 years. In this study, we try to find the electrical and thermal demand of IPs, and after that, the feasibility of a renewable energy park by considering the Kabul IPs metrological meteorology data. Moreover, The feasibility of having an eco-IP is analyzed in this research, and the results are presented accordingly.

Received: January 16, 2020; Revised: March 15, 2020; Accepted: March 20, 2020; Published: June 12, 2020

1. Introduction

IPs constitute the backbone and core of economic development in a country and can by no means be overlooked. However, the growth of industries requires a systematic context that is accompanied by basic industry-related facilities like Water, Electricity, Street, and Green Area. Without related facilities, an IP cannot stand on its feet. Electricity and heat are the initiative keys that the industry should have. Industry uses many energy sources; Afghanistan industrial sector uses a variety of energy sources, including electricity, coal, natural gas, petroleum, such as distillate and residual fuel oils and renewable sources. Mainly, solar, wind, and biomass. Afghanistan has 13 active, 12 inactive, and 11 under-planned IPs all around the country. The major IPs are located in Kabul, Herat, Balkh, Kandahar, and Nangarhar provinces.

Kabul is the capital of Afghanistan, and its available electricity is 373.5 MW, of which 68% (253.5 MW) is supplied from Uzbekistan and Tajikistan. 32% (120 MW) is supplied from Naghlu and Sorobi hydropower plants. 26.8% (100 MW) from the available sources has been consuming by the IPs [1]. In Kabul, many industrial activities have been happening, and three IPs, Pul-e-Charkhi, Jumah Mohammad Mohammadi (Bagrami), and Arghandeh have industrial activities. Kabul IPs have 519 factories, of which 399 are active. Among these active factories, 236 of them have their own land, and 163 factories running on rental land. The parks also have 98 inactive factories and about 22 remaining factories that Ministry of Commerce and Industry (MoCI) has no information about [2]. The total demand power of Kabul IPs is 180 MW, while DABS provides 90 MW only. Based on

Corresponding author: N Ebrahimi
Email: najib.ebrahimi1377@gmail.com

this, Kabul industries have electrical shortage of 80 MW (70 MW in Pul-e-Charkhi, and 10 MW in Arghandeh) [1].

Kabul IPs have various subsectors where, there are 13 main subsectors and 436 samples with an average sample size of 14.

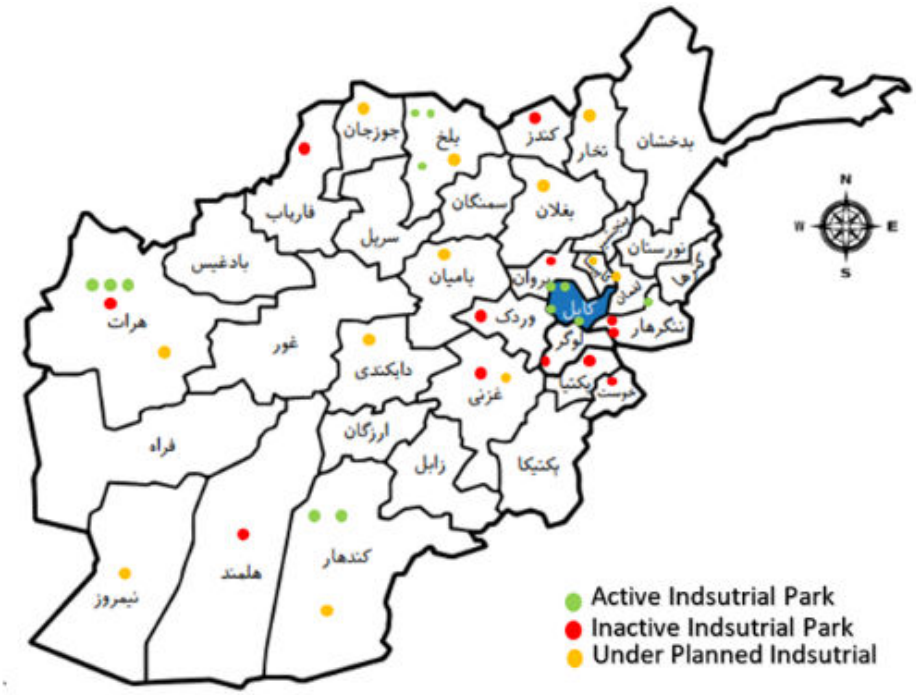

Figure 1. Afghanistan's active, inactive, and under-planned industrial parks [3].

Table 1: Overview of Kabul industrial parks subsectors.

Industrial Subsectors	Sample	Sample Industrial Subsectors
Chemicals and petrochemicals	143	Paint, detergent, shampoo, soap, washing powder, mosquito repellent coil, plastic bag, plastic carpets and mats, plastic basket, plastic pipe products, one-time usage dishes, pen, sponge production, kotex,pumper, wash the soil, separating gold from the soil, foam, PVC production, rubber tape, plastic head frame, shovel snow, plastic footwear
Nonmetallic minerals	47	Clay dashes, concrete and concrete-related product, rocks and stone cutting, coal, crushing plants, etc.
Textile and leather	26	Cotton production, leather manufacturing, carpet weaving, camping weaving, production of leather boots, creams, props and collars, clothes and production of the tire, tel boot, and rubber production
Food processing	28	silo bread, puree raisin, yam and cheese, tomato sauce, sweat meat, production of cakes and pies, cocoa, chips, flour production, jam, ketchup, etc.
Construction	39	Granulet, construction materials, building foam, construction work of sculptures, dig deep wells, rust and building block, etc.
Transportation	19	renting cars to offices and workshops
Beverage and tobacco	26	Natural water, fruit juice, soft drink, tobacco production, pot masala and Cornflour, oil production, biscuit making, macaroni, sausage, bottling and packing of beverage
Steel and iron melting	20	Iron melting and skull Gaul, steel factory
Nonferrous metal	30	Electric wire with copper, wire production, wood heater, grill, panel board, aluminum production, door and window making, water storage, production of aluminum containers and boiler production and Chodun
Pulp, paper, and printings	19	Printings, tissue paper, toilet paper, carton making
Medication	8	Oxygen production and paraffin production
Wood and wood products	24	Furniture and woodworking
Machinery	7	Water pump and solar fan
Total	436	

2. Kabul industrial parks

2.1. Pul-e-Charkhi industrial park

Pul-e-Charkhi IP is the largest IP in Afghanistan. Most of these IPs are located in 9th district of Kabul city.

Pul-e-Charkhi IP has 417 factories, of which 134 factories are active and have their own land, 163 factories are active with rental land, 98 factories are inactive.22 are unknown, and the MoCI does not have any information about [3]. Pul-e-Charkhi covers of 13 major industry subsectors. The sample size is approximately 14 samples per subsector [4].

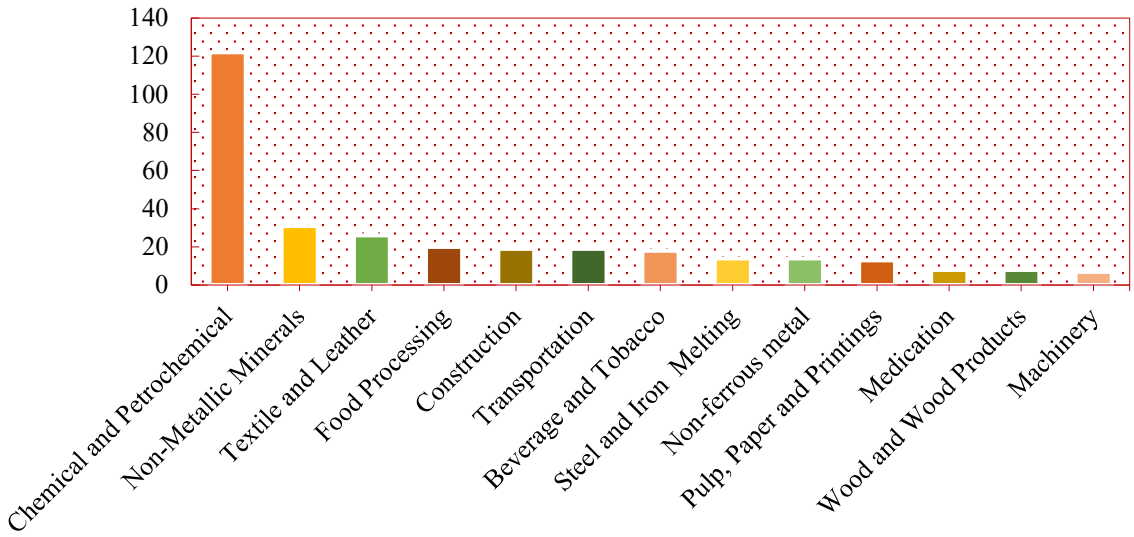

Figure 2. Pul-e-Charkhi industries subsector samples [2].

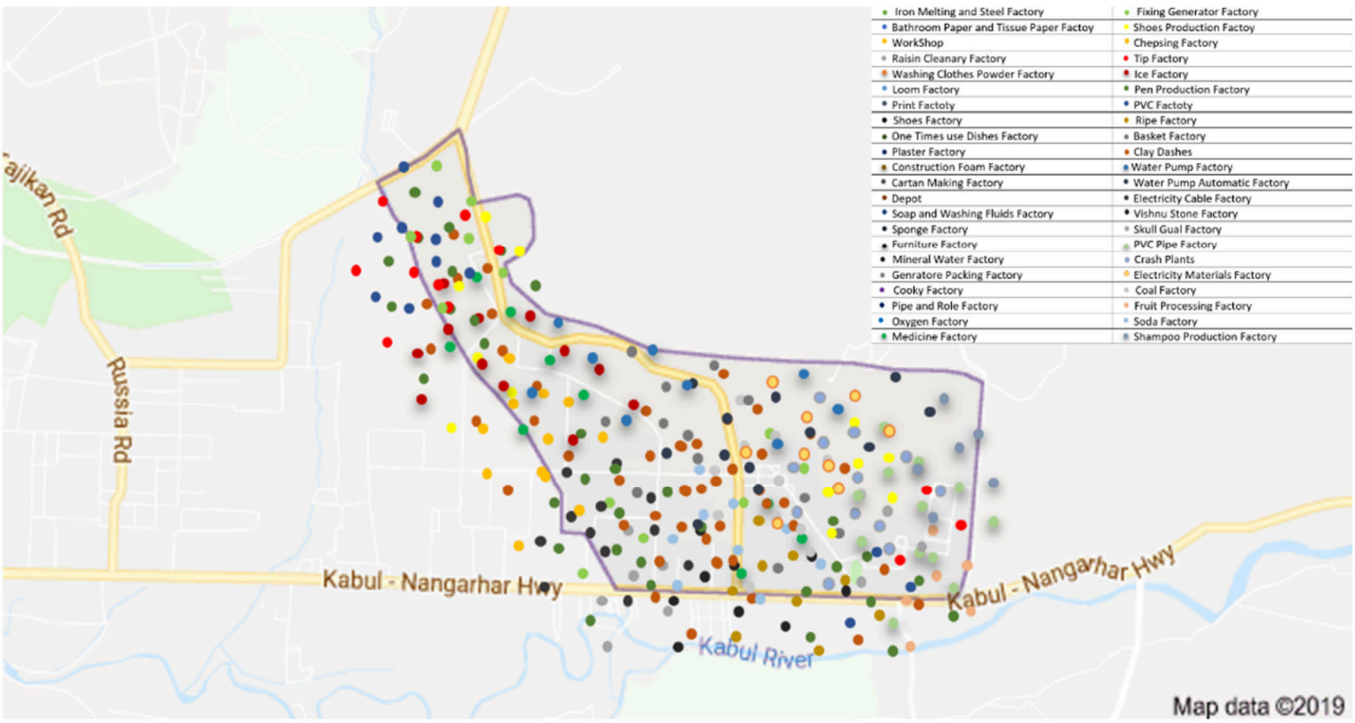

Figure 3. Location of Pul-e-Charkhi IP factories [5].

2.2. Jumah Mohammad Mohammadi (Bagrami) industrial park

Jumah Mohammad Mohammadi, which is also called by the name of Bagrami IP, is the newest IP located 7.5 km east of downtown Kabul, on the road to Bagrami district. This park contains 20-hector lands [6]. Jumah Mohammad Mohammadi (Bagrami) IP has two phases, Phase I and Phase II. It has 55 factories, all of them are active. 34 of them are in Bagrami Phase I and 21 are in Bagrami Phase II [2].

Bagrami IP consists 9 major industry subsectors. The sample size was to be around 6 samples per subsector. The final coverage was 55 samples [2].

Pul-e-Charkhi electrical necessity is about 140 MW, but 70 MW is provided by DABS and 20 MW will be provided by year 1399(Hejri-shamsi). Its eletric power is provided by the North and Bot Khak substations and in winter it is also fed by the Tara Khail substation [1].

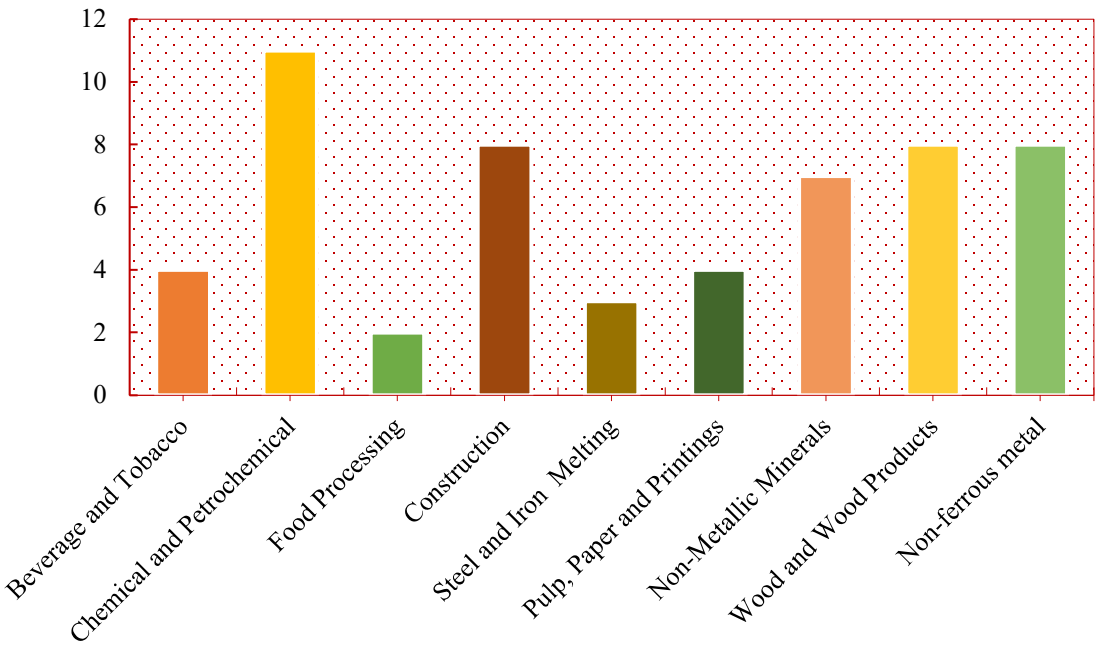

Figure 4. Bagrami Industries Subsector Samples [2].

Electrical demand of Jumah Mohammad Mohammadi (Bagrami) IP both in Phase I and Phase II is 20 MW and DABS until this time provides just 10 MW from Bot Khak substation, and this park has 10 MW of electricity shortage [1].

2.3. Arghandeh industrial park

The Arghandeh IP is located in the 5th district of Kabul city. Arghandeh has 23 parts of the land. It has 62 factories, all of them are active [2]. Arghandeh IP consists of 9 major industry subsectors. The sample size was to be around 7 samples per subsector. The final coverage was 55 samples [4].

Arghandeh electicity demand is 20 MW of which DABS provides 10 MW results on 10 MW shortages. Arghandeh provides its demand from Chamtala substation which has 22.9 km distance transmission line [6].

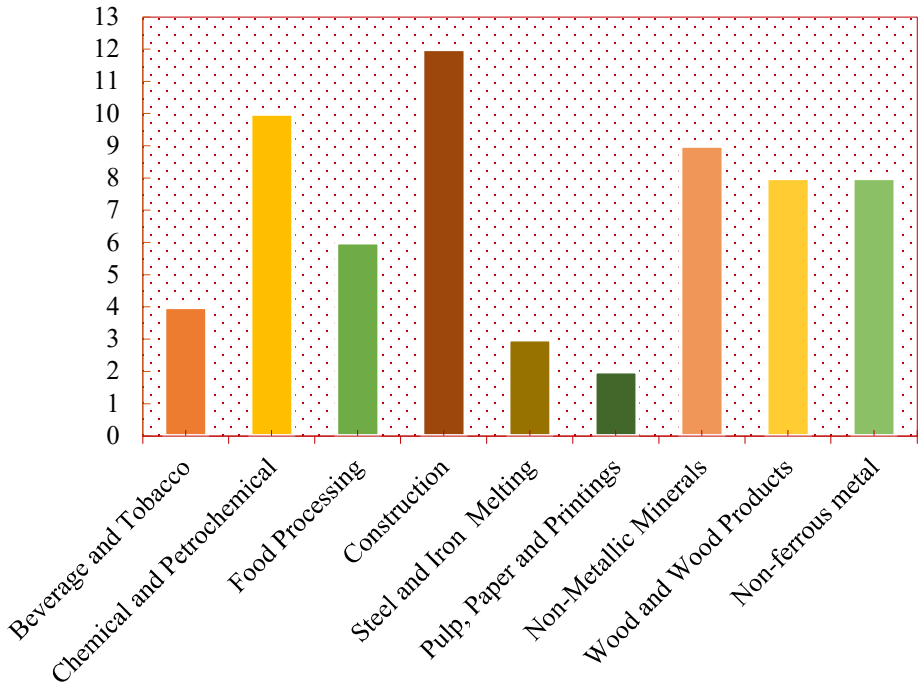

Figure 5. Arghandeh industry subsector samples [2].

Kabul has 13 subsectors: Chemicals and Petrochemicals, Nonmetallic Minerals, Construction, Nonferrous Metal, Food Processing, Textile and Leather, Beverage and Tobacco, Wood and Wood Products, Steel and Iron Melting, Transportation, Pulp Paper and Printing, Medication, and Machinery [4]. The subordinates of these subsectors in the three IPs have been surveyed and are listed in Table 2.

Table 2: Kabul IPs subsectors subordinators in each IP [3].

Industrial Sectors	Sample	Industrial Subsectors	Pul-e-Charkhi	Bagrami	Arghandeh	Total
Chemicals and Petrochemicals	143	Paint	7	0	0	7
		Detergent ,Shampoo, Soap, Powder	21	5	4	30
		Mosquito Repellent Coil	2	0	0	2
		Plastic Bag	11	2	0	13
		Plastic Carpets and mat	4	0	0	4
		Plastic Basket	5	1	0	6
		Plastic Pipe Products	4	1	0	5
		Washing Powder	16	0	0	16
		One-time usage Dishes	5	0	2	7
		Pen	2	0	0	2
		Sponge Production	4	0	0	4
		Cutix and Pumper	3	0	0	3
		Wash the soil, Separating gold from soil	1	0	0	1
		Foam	7	0	2	9
		PVC Production	17	1	2	20
		Rubber Tape and Plastic Head Frame	7	0	0	7
		Shovel Snow	2	0	0	2
		Plastic Foot Wear	4	1	0	5
Nonmetallic Minerals	47	Clay Dashes	13	3	5	21
		Concrete and Concrete-related product	4	1	1	6
		Coal	2	1	0	3
		Crush Plants	12	2	3	17
Construction	39	Granulet	4	2	5	11
		Construction Materials	4	1	0	5
		Building foam	5	0	1	6
		Construction work of sculptures	2	1	2	5
		Dig Deep Wells	2	2	2	6
		Rust and building block	2	2	2	6
Nonferrous Metal	30	Electric wire with copper	1	0	0	1
		Wire production	1	0	0	1
		Wood heater, Grill	1	0	0	1
		Panel Board	1	0	0	1
		Aluminum Production	3	3	2	8

		Door and Window Making	3	3	3	9
		Water Storage	1	1	1	3
		Production of Aluminum Containers	1	1	1	3
		Boiler production and Chodun	2	0	1	3
Food Processing	28	Silo Bread	2	0	0	2
		Puree Raisin Factory	2	0	0	2
		Yam and Cheese Factory	4	1	1	6
		Tomato Sauce	3	1	1	5
		Sweat Meat	2	0	0	2
		Production of Cakes and Pies	1	0	0	1
		Cocoa	1	0	2	3
		Chips	1	0	2	3
		Flour Production	1	0	0	1
		Jam	2	0	0	2
Textile and Leather		Ketchup	1	0	0	1
		Cotton production	3	0	0	3
		Leather Manufacturing	3	0	0	3
		Carpet Weaving	2	0	0	2
		Camping Weaving	2	0	0	2
		Production of leather boots, creams, props and collars	7	0	0	7
		Clothes	5	0	0	5
		Production of the tire, tel boot and, rubber production	4	0	0	4
Beverage and Tobacco	26	Natural Water	2	1	3	6
		Fruit Juice	2	0	0	2
		Soft Drink	2	0	0	2
		Tobacco Production	2	0	0	2
		Pot Masala and Cornflour	1	0	0	1
		Oil production	1	0	0	1
		Biscuit making	1	1	0	2
		Salt	2	0	0	2
		Macaroni	1	1	0	2
		Sausage	2	1	0	3
		Bottling and Packing of Beverage	2	0	1	3
Wood Products	24	Furniture	3	4	0	7
		Woodworking	5	4	8	17
Steel and Iron Melting	20	Iron Melting and Skull Gaul, Steel Factory	14	3	3	20
Transportation	19	Mobile Antenna	2	0	0	2
		Gas Company	7	0	0	7
		Renting Cars to Offices	2	0	0	2
		Workshops	8	0	0	8
Pulp, Paper and Printings	19	Printings	7	2	0	9
		Tissue Paper and Toilet Paper	4	1	1	6
		Carton Making	2	1	1	4
Medication	8	Oxygen Production	2	0	0	2
		Paraffin Production	6	0	0	6
Machinery	7	Water Pump	4	0	0	4
		Solar Fan	3	0	0	3
Total			319	55	62	436

3. Problem statement

Afghanistan is presently facing a difficult energy situation: electricity consumption from the national grid is principally lined by electricity imports from neighboring countries, like the Republic of Uzbekistan, the Republic of Tajikistan, and the Islamic Republic of Iran. Besides, an outsized share of the Afghan population, particularly in rural areas, still has no access to electricity.

Currently, Afghanistan's electricity demand is 915.5 MW. 620 MW (67.7%) is available and 373.5 MW (60.24%) has been consumed by Kabul Province [1]. The demand of Kabul is 620 MW but DABS can only provide 373.5 MW and 100 MW (26.8%) has been consumed by Kabul IPs [1]. Kabul IPs' electrical demand is 180 MW, but DABS can just provide 100 MW (55.6%), which means that there is an 80 MW (44.4%) shortage of electricity. According to the MoCI, the electricity shortage is responsible for 64% of industrial activities paralysis [1].

A survey was done by a researcher from Kabul IPs shows that to eliminate electric shortage, 25% of industries use diesel generator which costs 15AFN for every kWh compared to the grid which costs 6.75 AFN for every kWh. Kabul IPs consume daily of 141.86 tons (131.96 tons of Coal, 2,884.24 m^3 Gas, and 335.45 Barrel Oil) of fossil fuel for their thermal and electrical shortage.

Besides that, burning fossil fuel creates a phenomenon by the name of climate change and it is a

lifetime enemy. Moreover, Afghanistan Meteorology Organization (AMO) claims that Kabul IPs are responsible for 30% of greenhouse gases (GHGs) emissions [7]. Electrical Shortage decreases industrial activity in Kabul IPs, especially in winter when industrial activity decreases to 40% [4]. Kabul IPs pay a huge amount of taxes to Afghanistan Environment Organization (AEO) for burning fossil fuels and environmental emissions.

4. Solution mechanism

Afghanistan is a country that faces several challenges in different aspects. One of the biggest problem is low access to electricity, but this problem is not only related to the residential sector. This problem also strikes the industrial sector. The demand for energy is growing very rapidly, so to meet this growing demand, first of all, a country must have a reliable and efficient energy system, to have a stable condition. One of the primary and best ways to solve this problem is the usage of renewable energy sources such as solar, wind, hydro and geothermal energy. RE integration in industrial assets brings direct benefits to the industrial players and the government. Some key benefits of RE application in industries are the following: increased productivity, improved energy supply reliability, reduced load from DABS, additional revenue-generating opportunities, greater coherence with corporate environmental and local commitments, and reduced energy costs and price hedging from future increases of fuel and grid prices.

Usage of renewable energy resources is not a brand new discussion within the industry. it has started since the industriesgrew. Industries used to burn wood and coal for metal treatment million years ago. When hydropower and turbines in the mill came into use, that resulted in revolution of using energies like coal and fossil oil within the 19th century.

Afghanistan has enormous renewable energy resources with excellent to fairly good generation potential. These resources are spread over wide geographical areas throughout the country, in contrast to other conventional energy resources, which are concentrated in specific area.

These resources can also notably provide sustainable power to the existing grid and future expansion.

Afghanistan can produce around 318 GW of electricity utilizing available renewable energy sources in the country through a diverse renewable energy portfolio representing Hydro (23,000 MW), Wind (67,000 MW), Solar (222,000 MW), Geothermal (3,000 – 3,500 MW), and Biomass (4000 MW) [8].

Finally, renewable energy cannot replace conventional fuels in the IPs due to technology. Renewable energy can only be used as an assistant energy resource in the IPs, also, it can reduce fossil fuel consumption and environmental impact.

5. Results and discussion

For applying this research, descriptive and questionnaire methods, both have been used. In this study, largest renewable energy parks that have been installed for providing the energy need of IPs in countries such as India, China, the United Arab Emirates (UAE), the United States of America (USA), Germany, and Spain were evaluated

Afterward, the related industrial data was collected from the MoCI, Afghanistan Chamber of Commerce and Industry (ACCI), and DABS.

Then, because of the lack of information, Pul-e-Charkhi IP has been surveyed to find thermal demand, electrical demand, and the amount of money paid by the IP. Besides, the proper areas near each Kabul IP and its status wasfound from the Ministry of Urban Development and Housing (MoUDH) The metrological condition of the area is researched. Moreover, by considering the obtained data , the proper renewable resource selected, and, in the end, its economic analysis wascalculated.

Afghanistan is gifted with a vast potential of renewable energies, and every point of this country has mdifferent climate, so building a renewable park site is a key point. Because of the nearness of the Pul-e-Charkhi and Bagrami IPs, one area has been selected to energize both parks, which is the Deh Sabz area.

Table 3: Kabul IPs energy consumption [2].

Industrial Subsectors	Sample	Industrial Subsectors	Coal (Ktoe)	Electricity (Ktoe) (8hr/day)	Gas (Ktoe)	Total (Ktoe)

Chemical and Petro-chemical	143	Paint, Detergent, Shampoo, Soap, Washing Powder, Mosquito Repellent Coil, Plastic Bag, Plastic Carpets and mat, Plastic Basket, Plastic Pipe Products, One-time usage Dishes, Pen, Sponge Production, Cutix, and Pumper Wash the soil Separating gold from soil, Foam, PVC Production, Rubber Tape and Plastic Head Frame, Shovel Snow, Salt, Plastic Foot Wear	0.09	6.93	0.13	7.1481
Nonmetallic Minerals	47	Clay Dashes, Concrete and Concrete-related product, Rocks and stone cutting, Coal, Crush Plants, etc.	25.38	7.49	0.02	32.8903
Construction	39	Granulet, Construction Materials, Building foam, Construction work of sculptures, Dig Deep Wells, Rust and building block, etc.	0	4.34	0.04	4.3836
Nonferrous Metal	30	Electric wire with copper, Wire production, Wood heater, Grill, Panel Board, Aluminum Production, Door and Window Making, Water Storage, Production of Aluminum Containers and Boiler production, and Chodun	0.15	5.03	0.05	5.2362
Food Processing	28	Silo Bread, Puree Raisin, Yam and Cheese, Tomato Sauce, Sweat Meat, Production of Cakes and Pies, Cocoa, Chips, Flour Production, Jam, Ketchup, etc.	0	1.01	0.03	1.0435
Textile and Leather	26	Cotton production, Leather Manufacturing, Carpet Weaving, Camping Weaving, Production of leather boots, creams, props and collars, Clothes and Production of the tire, tel boot and rubber production	0.59	1.55	0.03	2.1723
Beverage and Tobacco	26	Natural Water, Fruit Juice, Soft Drink, Tobacco Production, Pot Masala and Cornflour, Oil production, Biscuit making, Macaroni, Sausage, Bottling and Packing of Beverage	0	0.88	0.06	0.9388
Wood and Wood Products	24	Furniture and Woodworking	0	4.60	0.02	4.6236
Steel and Iron Melting	20	Iron Melting and Skull Gaul, Steel Factory	7.71	7.17	0.32	15.2051
Transportation	19	Renting Cars to Offices and Workshops	0	0.76	0.05	0.8025
Pulp, Paper, and Printings	19	Printings, Tissue Paper, Toilet Paper, Carton Making	0	2.76	0.06	2.8224
Medication	8	Oxygen Production and Paraffin Production	0	1.67	0.02	1.6852
Machinery	7	Water Pump and Solar Fan	0	0.36	0.004	0.3638
Total	436	Ktoe	33.93	44.57	0.82	79.32
			Coal Annually Consumption	Electricity Annually Consumption	Gas Annually Consumption	

The meteorology of Deh Sabz shows that wind energy is not the proper option for energizing Bagrami and Pul-e-Charkhi IPs due to the low speed of wind at 50 m height (3.3-3.4 m/s) and at 100 m height (3.97 m/s) as estimated by Wind Atlas.

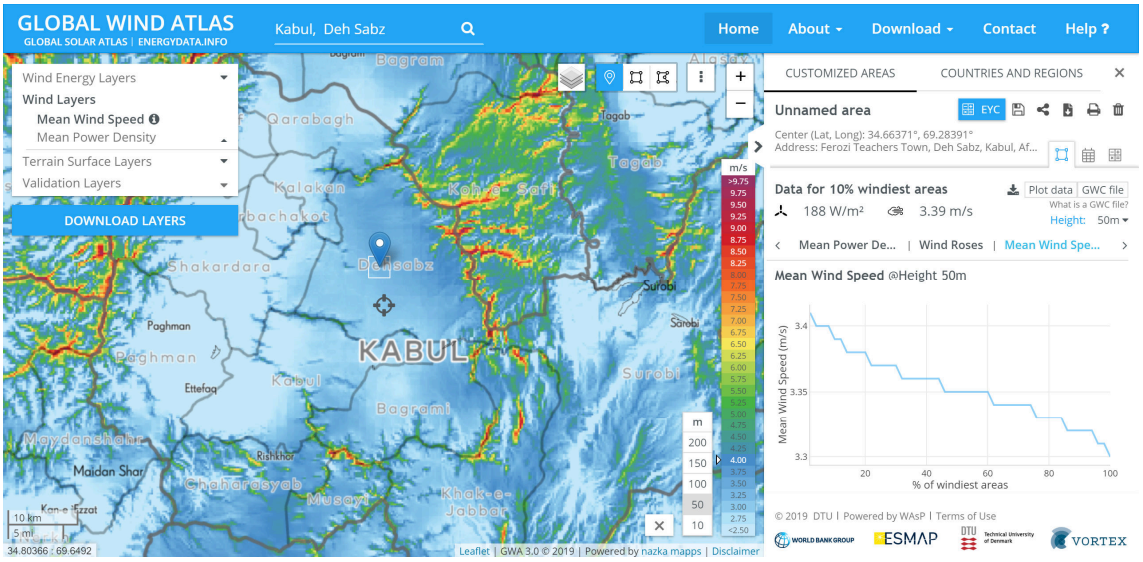

Figure 6. The mean wind speed at Deh Sabz, Kabul (at 100m) *[9]*.

For Arghandeh IP, the proper area is Arghandeh Bala and its meteorological data shows that wind energy is also not suitable due to the low speed of 2.26 m/s at 50 m heightand 2.28m/s at 100 m height as estimated by Wind Atlas (Globalwindatlas, 2019).

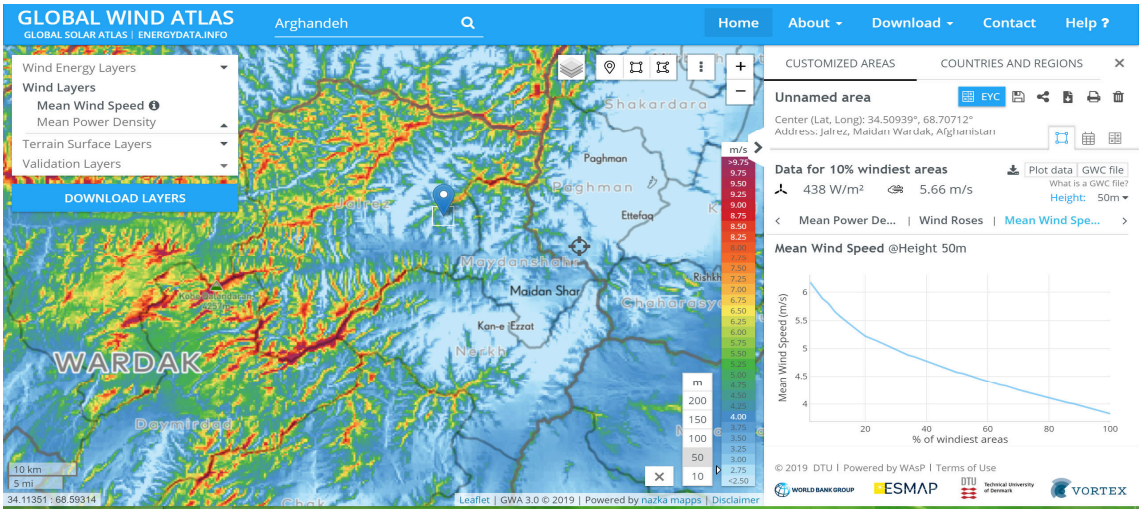

Figure 7. The Mean Wind Speed at Arghandeh Bala, Kabul (at 50m) *[10]*.

Finally, based on this analysis, we can say that Kabul province does not have the economic wind potential to harness for helpful usage. Simply we can install some little and first wind turbines with low power and use them to charge batteries, light the yard, or build circumference lamps or for any different primary usage. It is possible to put wind turbines in this space to generate energy by wind. Sorobi area might be appropriate place to utilize wind turbines due to being on the brinks of the Naghlu dam and conjointly on the brinks of a substation and transmission lines. Conjointly, it is placed on an excellent road that whenever the potential wind speed gets slow and the turbines cannot manufacture the economic wind generation, then we can use energy from another source like that electricity grid from the substation and transmission lines and also from the Naghlu dam.

6. Feasibility of geothermal plant

Afghanistan also has a huge amount of geothermal energy and Kabul has many faults which supports the claim that there are more geothermal energy sources, but due to the lack of investigation, we cannot use energy from this source so far.

7. Feasibility of hydro plant

Hydro energy is low for Kabul, but the only interior source which supplies an amount of Kabul electrical demand is hydro energy, which is supplied from Naghlu hydro plant and Sorobi hydro plant. Hydro energy has a 15% share in generating electricity [11]. However, it is not suitable due to the low amount and also the unbalanced generation which lasts only for 6 months due to water flow variation.

8. Feasibility of solar energy

Kabul Province is one of the provinces with the best solar installation capability and 300 sunny days in a year. It has different solar irradiance every month.

The highest insolation of Kabul Province is in the month of August (Asad) of 7,348 Wh/m^2/day and the lowest all-time insolation is in the month of January (Jadi) of 3,338 Wh/m^2/day. The average insolation of Kabul province is 5,910 Wh/m^2/day. Deh Sabz area has excellent potential for generating thermal and electrical energy, as shown in the below figures.

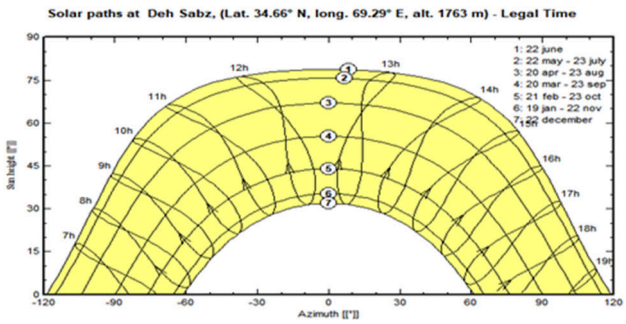

Figure 8. Solar path at Deh Sabz, Kabul.

Deh Sabz project area is elevated 1,797 meters (5,896 feet) above sea level in a narrow valley with a gradient of 1.5 to 2 % and the land being almost flat [12]. The climate of the area is typical of a semiarid steppe climate having a mean temperature of the area varying between -2˚C to 46˚C. Much of the rain falls during the winter season (December to February) and some in the summer season (July to September).

Considering Kabul's great solar potential in both parks (Deh Sabz and Arghandeh Bala) hybrid power plant of Solar PVs and CSP has been designed. Here more CSPs than Solar PVs have been designed because CSP can make electricity when the sun is no longer shining and at times when it may be most valuable to the grid. This storage lets CSP systems extend the "shoulder hours" of their generation patterns and generate electricity a few hours before the sun rises and a few hours after it sets, making it easier to integrate electricity from such plants into the grid. In the bellow boxes for building a solar plant, AC 400W Sun Power company is considered as specified in table 4.

Table 4: Selected module specification *[13]*.

AC 400W Sun Power Solar Panel (SPR-A400-G-AC)	
Inverter Modal: SPWR-A4	@240 VAC
Peak Output Power	366VA
Maximum Continuous Output Power	349VA
Nominal (Line-Line) Voltage (V)	240 / 211-264
Maximum Units per 20 A (L-L) Branch Circuit	1.45
Max. Units per 20 A (L-L) Branch Circuit	11
CEC Weighted Efficiency	97.0%
Nominal Frequency	60 Hz
Extended Frequency Range	47-68 Hz
AC Short Circuit Fault Current Over 3 Cycles	5.8 A rms
Overvoltage Class AC Port	3
AC Port Back feed Current	18 mA
Power Factor Setting	1.0
Power Factor (Adjustable)	0.7 lead. / 0.7 lag.
Nominal Power	400W
Dimensions	1016mm*1835mm*33mm
Power Tolerance	+/-3%
Module Efficiency (%)	21.5
Temp. Coefficient (Power)	−0.29%/°C
Shade Tolerance	Integrated module-level max. PowerPoint tracking
Price/module	33000 AFN
STC: Irradiance 1000W/m^2, Modules Temperature 25°C, AM=1.5	

For CSP, Heliotrough CSPscollector is selected . The Heliotrough uses a torque tube as a central stabilizing element. One module has a length of 19.1 m. A collector assembly consists of 10 modules and is 191 m long. The Heliotrough collector is one of the first designs with a bigger aperture width compared to the former collectors. While most previous collectors had an aperture width of 5.76 m, the Heliotrough aperture width is 6.77 m. This goes along with larger absorber tube diameters (90 mm instead of 70 mm).

9. Deh-Sabz plant design

Deh Sabz plant is designed for providing the electrical and thermal necessity of Pul-e-Charkhi and Jumah Mohammad Mohammadi (Bagrami) IPs. Deh Sabz plant is designed for generating 160 MW electricity and 80 toes thermal demand and two-day backup. In this research we also rely on CSP rather than PVs which thermal demand is completely provided by CSP and 120 MW of electricity also provided by CSP. Because, compared with the solar photovoltaic (PV) system, the concentrated solar thermal system is economical and more efficient. It eliminates the use of costly PV cells and alternating current (AC) inverters. It is, however, limited to large-scale applications. It is considered that the power plant will only cater to the industries working from 8:00 AM to 4:00 PM.

Through the major disadvantages of Solar PVs and especially the storage problem, 40 MW of solar power plant is installed, and the remainders are provided from the CSP plant.

10. Deh Sabz solar plant calculations

Pul-e-Charkhi and Bagrami IPs' electrical demand is also 160 MW which is installed by 40 MW of solar power plant and the remainders from CSP plant. It is worth of mentioning that 400 W AC solar panel is considered for this area.

Number of Solar Panels = 40MW/400 = 100,000 Solar Panels

Module interrow spacing:

Height Difference = sin(Tilt Angle) * Module Weight

Height Difference = $\sin(36) * 1.016 = 1.20$ m

Module Row Spacing = Height Difference / tan 17

Module Row Spacing = 1.20/tan 17 = 3.87 m

Number of Strands = 250 Solar Panels were connected in series in a string

Number of Rows = 400

Area covered by Solar Power Plant = 235m*1954.4m = 459,284 m^2 = 230 Jerribs = 45.93 Hectares = 0.46 km^2

Deh Sabz CSP plant is considered to install 120 MW electricity and 80 toes thermal demand. It has been proposed that the power plant will only cater to the industries working from 8:00 AM to 4:00 PM.

Deh Sabz concentrating solar plant (CSP) calculation:

CSP plant is designed for 120 MW and 80 toes thermal energy which is equal to

120MW * 8hr = 960MWh = 82.55 toes

Total demand:

82.55 toes + 80 toes =162.55 toes

Area covered by solar power plant:

Area of CSP plant is variable, but according to numerous CSP plants, a 1MW CSP with 14 hours of storage required 12 Hectars.

Area = 120 * 12 $(100\ m)^2$ =14,400,000m^2=7200 Jerribs = 1440 Hectors=14.4 km^2

Which the amount generating heat is sufficient for its thermal demand.

The major materials of a CSP plant and PV plant are Solar Panel, Parabolic trough CSP, Storage system, Labor, Land, and frame. According to Indian expert cost of 1 MW, CSP with 12-hour storage is 20 crores [14]. AC solar panel cost is 33000 AFN, and average labor cost is 400 AFN per day, a frame which contains 14 Solar PVs costs 11000 AFN, and 1 Jerrib land cost is 1,200,000 AFN.

Table 5: Cost analysis of Deh Sabz plant.

Items	Numbers	Cost ($ million)
Solar Panel	100000	42.31
Frame	100000	1.01
Land (Jerrib)	7200	110.77
Labor AFN/day)	400	0.0923
[Parabolic Through CSP + Storage] (MW)	20000	338.46
Total ($ Million)		492.64

11. Arghandeh Bala Plant Design

Arghandeh IP is one of the recent IPs in which the total electricity demandbased on a DABS, is estimated to be 15.9 MW. It annually utilizes 20.3 toes of thermal energy.

Arghandeh Bala plant is designed for providing the electrical and thermal necessities of Arghandeh IP. Arghandeh Bala plant is designed for generating 20 MW because of transmission losses of electricity and 25 toes of thermal demand and 2-day backup. It is relied on CSP rather than PVs in this research which thermal demand is entirely provided by CSP and 15 MW of electricity is also provided by CSP because compared with the solar photovoltaic (PV) system, the concentrated solar thermal system is economical and more efficient.It also eliminates the use of costly PV cells and alternating current (AC) inverters. However it is limited to large-scale applications. It has been proposed that the power plant will only cater to the industries working from 8:00 AM to 4:00 PM.

Due toThrough the major disadvantages of solar PVs and especially the storage problem, It is just installed 5 MW of solar power plant and the remainders are provided from the CSP plant.

Solar plant calculation for Arghandeh IP:

Installing a 5 MW solar plants by using 400 W AC solar panel.

Number of Solar Panels = 5 MW/400 = 12,500 Solar Panels

Module interrow spacing:

Height Difference = sin(Tilt Angle) * Module Weight

Height Difference = sin(36) ∗ 1.016 = 1.20 m

Module Row Spacing = Height Difference / tan 17

Module Row Spacing = 1.20/tan 17 = 3.87 m

Number of Strands = 100 Solar Panels were connected in series in a string

Number of Rows = 125

Area covered by Solar Power Plant = 184 m*610.75 m = 112,378 m^2 = 56.2 Jerribs = 11.24 Hectares = 0.11 km^2

Arghandeh Bala CSP plant is considered to install 15 MW electricity and 25 toes of thermal demand.

Arghandeh Bala CSP calculation:

CSP plant is designed for 15 MW and 25 toe thermal energy which totally equal to:

15 MW * 8hr = 120 MWh =10.32 toe

Total demand:

10.32 toe + 25 toe= 35.32 toe

Area covered by solar power plant:

Area of CSP plant is variable, but according to numerous CSP plants, a 1 MW CSP with 14 hours of storage required 12 Hectars.

Area = 15 * 12 $(100\ m)^2$ =1,800,000 m^2=900 Jeribs = 180 Hectors=1.8 km^2

Which the amount generating heat is sufficient for its thermal demand.

According to Indian expert cost of 1 MW, CSP with 12-hour storage is 20 crores [14]. AC solar panel cost is 33000 AFN, and average labor cost is 400 AFN per day, a frame which contains 14 Solar PVs cost is 11000 AFN, and 1 Jerrib land cost is 400,000 AFN.

Table 6: Cost analysis of Arghandeh Bala plant.

Items	Numbers	Cost ($ million)
Solar Panel	12,500	5.29
Frame	12,500	0.13
Land (Jerrib)	956	4.90
Labor AFN/day)	400	0.0923
[Parabolic Through CSP + Storage] (MW)	15	42.31
Total ($ Million)		52.72

12. Economic analysis

Afghanistan depends heavily on neighboring countries for nearly all its energy needs, eightieth of its commerce power and ninety-seven of fuel necessities. This has huge implications for rustic with scarce interchange reserves. The energy import bill exaggerated by an element of fourteen, from $16 million in 2007 to almost $224 million in 2015. In 2018 the Islamic State of Afghanistan solely offered twenty-fifth of its electrical demand and it has confidence in its neighboring countries to complete their seventy-fifth electrical demand and annual paying of $264 million (Energy, 2019).

Currently, Afghanistan's electrical demand is 915.5 MW, 620 MW (67.7%) is available, and 373.5 MW (60.24%) has been consumed by Kabul Province [15]. The demand of Kabul is 620 MW, but DABS can only provide 373.5 MW, and 100 MW (26.8%) has been consumed by Kabul IPs. Kabul IPs' electrical demand is 180 MW but DABS can only provide 100 MW (55.6%), which means that there is 80 MW (44.4%) shortage of electricity [15]. According to the MoCI, the electrical shortage is 64% responsible for industrial activities paralysis [16].

Electrical shortage decreases industrial activity in Kabul IPs, especially in winter in which industrial activity decreases to 40%. The renewable energy industry in Afghanistan is in its infancy. However, it presents an opportunity for the country to reduce its energy import bill, especially for power.

Kabul IPs utilize annually 180 MW electricity at 8-hour duration, which is 100 MW for every kWh. It pays AFN 6.75 for DABS and the remainder is 80 MW, which is generated by burning petroleum with the cost for every KWh being AFN 15. Its annual coal consumption is 25,000 tons and the cost of every ton of coal is 5500 AFN. The annual gas consumption is 1,587,438 Kg gas; its average cost is 45 AFN [4].

Kabul IPs pays annually $73.01 million (5.695 Milliard AFN) and the total cost of building the hybrid renewable energy plant is $545.36 million (42.38 Milliard AFN). The payback time is 7.5 years.

13. Social and environmental analysis

Afghanistan is connected to its neighboring countries and it imports a lot of commodities from them.This has its effects on the country's economy. Although Afghanistan has a great potential of RE sources, a huge amount of its energy is supplied from neighboring countries. By considering the above problems and opportunities, Renewable Parks has been selected in this research.

- Building Renewable Parks achieves the following benefits:
- Reducing energy costs and price hedging from future increases in fuel and grid prices;
- Saving huge amounts of money;
- Improving energy supply and reliability;
- Creating more job opportunities;
- generating additional revenue opportunities;
- Creating greater coherence with environmental corporates and local commitments
- Covering useless land.

14. Conclusion

This study considers an overview of providing electrical and thermal energy needs of Kabul IPs from RE sources and the feasibility of renewable sources in Deh Sabz and Arghandeh Bala Kabul. The data in this study are collected through government institutions and questionnaires from the industry owners, and based on the analysis of the concerned data, it is concluded that the best way to support DABS and have a reliable, affordable, and the friendlier energy source is the usage of RE sources. According to the site studying of Kabul IPs (Deh Sabz and Arghandeh) it appeared that the best sources of renewable energies are Solar PVs, CSPs, and geothermal energy.

Renewable energy can only be used as an assistant energy resource in the IPs, and it can reduce electrical shortage and fossil fuel consumption and environmental impacts. So we should have some nonrenewable auxiliary plant to support other plants at peaks.

In the end, it should be emphasized that every country stands on its economy, and the economy relies on industrial sectors and the industrial sectors rely on initial facilities like Energy, Water, roads, green areas for living and a suitable space for physical activities. Energy is a key element for IPs and the government should provide energy for IPs.

References

[1] Da Afghanistan Breshna Sherkat (DABS) (**2019**) "Afghanistan industrial parks electricity necessity" (https://moci.gov.af/en/industrial-park) *Accessed*: *9 December **2019***

[2] Ministry of Commerce and Industry (MCI) - Afghanistan (**2019**) "Industrial data" (https://moci.gov.af/en/industrial-park) *Accessed*: *14 October **2019***

[3] Ministry of Commerce and Industry (MoCI) - Afghanistan (**2019**) "Industrial Parks" (https://moci.gov.af/en/industrial-park) *Accessed*: *9 December **2019***

[4] Najibullah E (**2019**) "Industrials" (Industrial Parks, Ministry of Commerce and Industry (MoCI) - Afghanistan)

[5] Negah Y (**2019**) "Annual report" Kabul, Afghanistan, *Afghanistan Chamber of Commerce and Industry (ACCI)*. (https://www.acci.org.af/media/Annual%20Report%20English.pdf) *Accessed*: *1 October **2019***

[6] Directorate of Analysis And Evaluation - Afghanistan Investment Support Agency (AISA) (**2013**) "Industrial parks in Afghanistan: Growth, challenges and recommendation" *Analytical report* Kabul, Afghanistan, *Directorate of Analysis And Evaluation - Afghanistan Investment Support Agency (AISA)*. (https://iccia.com/sites/default/files/library/files/Industrial%20Park%20Report.pdf) *Accessed*: *1 November **2019***

[7] Afghanistan meteorology data (**2019**) *Afghanistan Meteorology Organization (AMO)* (http://www.amd.gov. af) *Accessed*: *14 November **2019***

[8] Anwarzai MA (**2018**) "Research and analysis of Afghanistan's wind, solar, and geothermal resources potential" (Doctoral Dissertation) Tokyo, Japan, *Search Results Web results Tokyo University of Agriculture and Technology* (https://tuat.repo.nii.ac.jp/?action=repository_action_common_download&item_id=1487&item_no=1&attribute_id=16&file_no=1) *Accessed*: *4 July **2020***

[9] Map showing the location of Deh Sabz, Kabul, Afghanistan (100m) (**2019**) (https://globalwindatlas.info) *Accessed*: *28 November **2019***

[10] Map showing the location of Deh Sabz, Kabul, Afghanistan (50) (**2019**) (https://globalwindatlas.info) *Accessed*: *28 November **2019***

[11] Ministry of Energy and Water (MEW) - Afghanistan (**2018**) "Afghanistan agrometeorological bulleting" (http://mew.gov.af/) *Accessed*: *1 November **2019***

[12] Central Statistics Organization (CSO) - Afghanistan (**2019**) "Statistical indicators in Kabul province" Kabul, Afghanistan, *Central Statistics Organization (CSO) - Afghanistan*.

[13] SunPower (**2019**) "400–425 W residential AC module" (https://us.sunpower.com/sites/default/files/

spr-a-series-425-415-400-g-ac-datasheet-532618-revb.pdf) *Accessed*: *7 July* ***2019***

[14] Singal L, Harats Y (**2016**) "Hybrid renewable energy parks" (https://www.researchgate.net/profile/Lavleen_Singal/publication/303371155_Hybrid_Renewble_Eergy_Parks/links/573ec7ce08ae9f741b31dbd5/Hybrid-Renewable-Energy-Parks.pdf?origin=figurs Dialog) *Accessed*: *1 November* ***2019***

[15] Ministry of Energy and Water (MEW) - Afghanistan (**2019**) "Afghanistan energy condition" (http://mew.gov.af/) *Accessed*: *1 November* ***2019***

[16] Ministry of Commerce and Industry (MCI) - Afghanistan "Industries development" (https://moci .gov.af/en/industrial-park) *Accessed*: *14 October* ***2019***