

## Applications of Renewable Energy in Yemen

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### Abstract

In recent years, Renewable Energy technologies have become the most important and promising sources of energy to meet the ever-increasing energy demands. Concerning Yemen, which is one of the least developed countries in the Middle East, it is depending mainly in the electricity production on fossil fuel. These resources have many challenges for the long-term use due to the high-priced costs, unsustainability, and environmental and climate changes. This research proposal will focus mainly on the application of four renewable energy resources namely wind, solar, biomass, and geothermal energy in Yemen. It will study and analyze the various aspects and challenges of these resources to meet our country high energy-demanding. It will reliably collect the data, study the areas which are suitable for renewable energy projects, and approximate the power potentials in GW in Yemen for the future implementations

**Keywords:** Renewable energy; Climate; Solar, Biomass, Geothermal

### Introduction

Recently, Yemen is facing a great power shortage which doesn't meet its population and infrastructure power demands. In 2009 the installed capacity of electricity was approximately around 1.6 GW which in fact has a power supply gap in demand of around 0.25 GW. The Power Development Plan (PDP) forecasted and estimated an amount of 3.5 GW of capacity demand for the year 2020. In 2011, the power capacity has dropped to less than 70% of the overall capacity due to the anti-government demonstrations, strikes on oil pipelines, and evacuation of foreign staff. This became worst in 2015 when the situation in Yemen turned into internal and external conflicts [1]. Now, if we leave the war and conflicts aside because they will end soon and focus on the real obstacles of power generation in Yemen, we will come across how to find optimum solutions for that [2]. One of the great challenge and the sacristy of electricity in Yemen is that it depends totally on fossil fuel including, Diesel, Heavy Crude Oil (Mazot), and Liquefied natural Gas (LNG). These resources are of a great concern due to environmental and economical concerns [3-5]. Also, the geographical nature of Yemen which consists of rural areas implements other challenges on power distribution. Rural population is about 75% of the total population and gets only 23% of the power supply. The industrial activity is very weak due to unavailability of continuous power supply and the major use of electricity is for the household purposes as shown in Figure 1.

All these challenges contribute to leave an enormous gap in the power supply in Yemen. On the other hand, Yemen is rich in renewable energy resources such as wind, solar, biomass, geothermal, and hydropower energies. These abundant resources in Yemen are potentially enough to produce electricity in order to fill this existing energy gap [6].

This research proposal will conduct feasible studies, collecting reliable data, concerning about the technological aspects, and making appropriate models and simulations of the future renewable energy projects in Yemen. In establishing such projects, there are many challenges which account for the low applications of renewable energy in Yemen. Among these is the lack of the qualified personnel in the field of renewable energy. Also, another challenge is the lack of reliable data about the geology and the weather of Yemen. So, this research will try to overcome these obstacles by investigating more tangible solutions to bring about renewable energy projects in Yemen to reality [7,8].

### Discussion

This research project will present four possible renewable energy

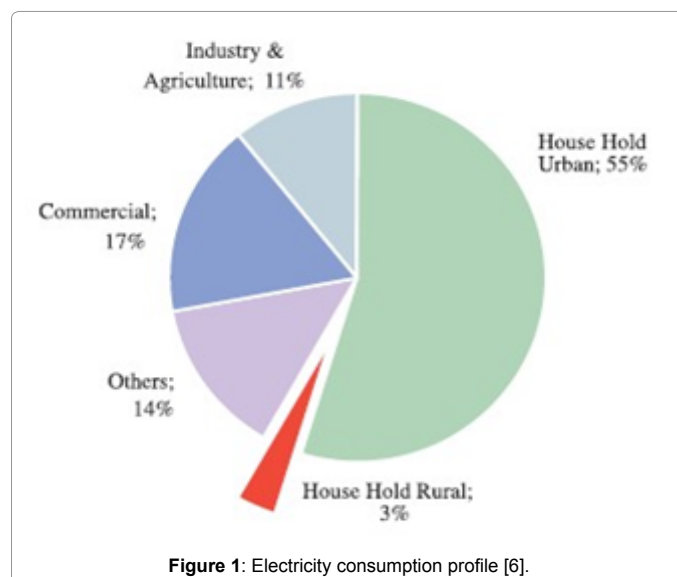


Figure 1: Electricity consumption profile [6].

projects in Yemen which are related to wind, solar, biomass, and geothermal energy. These projects are briefly presented:

### Wind energy

Yemen has a long coastal strip of over than 2500 km long and an average width of 45 km along the Red Sea, and the Arabian Sea. These coastal areas have an annual wind speed average of more than 8 m/s. There is a good potential for making wind farms on the coastal strip as well as on the offshore areas. One of the most suitable coastal areas is Al-Mokha Zone, Taiz, Yemen which has favorable conditions of wind

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in Yemen. According to Egyptian experts study, it was estimated that from an area of 300 km<sup>2</sup> (Figure 2) alone in Al-Mokha, it can produce 1.8 GW power of electricity.

In my final year at the Mechanical Engineering Department, Sana'a, University, our graduation research project was to work directly with the Ministry of Electricity to design a wind turbine to work in Al-Mokha zone and to study its feasibility. Our wind turbine was rated to produce 2 MW of power with the average wind velocity at height 80m is 8.54 m/s as shown in Table 1.

This area occupies 600 km<sup>2</sup> onshore and offshore, and it is suitable to produce 3 GW if we install 1500 such turbines. Figure 3 shows an area of 48 km<sup>2</sup> which is capable of producing 240 MW of power.

The mechanical design and simulation of the wind turbine rotor blade has been carried out in SOILDWORKS as shown in Figure 4. The diameter of this wind turbine is 90 m and the hub height is 80 m.

This is just the power that can be utilized from Al-Mokha Zone, Taiz. Other places in Yemen can be studied in similar way such as the Gulf of Aden and Al-Hudaydah which are coastal areas in order to produce electricity from wind energy. We are committed to collect more data and further investigate these places for the future use to produce power from wind resources.

Solar energy

Beside wind energy, Yemen is one of regions in the Middle East which has the highest levels of solar radiation of around 5.2-6.8 kW/m<sup>2</sup> per day. The shining hours per day is averaged by more than 8 hours. This can be used to harness the heat and the light from the sun to produce electricity using photovoltaic (PV) systems. It is feasibly applicable for Yemen to use two applications of solar power supply either centralized (on-grid) which can be used in larger farms or decentralized (off-



Figure 2: Area of 300 km<sup>2</sup> in Al-Mokha zone capable of producing 1.8 GW [10].

	Resource Grid Heights (m)						
Mean Values	39	55	60	65	70	78	80
Mean Speed (m/s)	7.3	7.84	8	8.15	8.29	8.49	8.54
Power Density (W/m <sup>2</sup> )	406	490	517	543	568	605	614

Table 1: Mean values of wind speed in Al-Mokha by WASP at different heights [2].

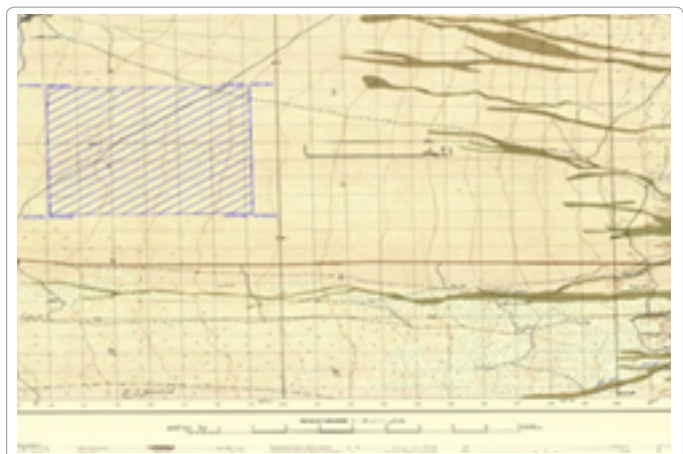


Figure 3: Area of 48 km<sup>2</sup> in Al-Mokha zone [3].

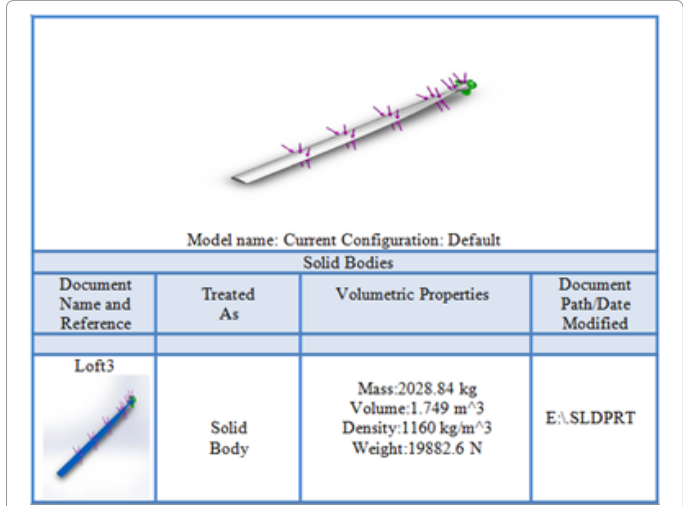


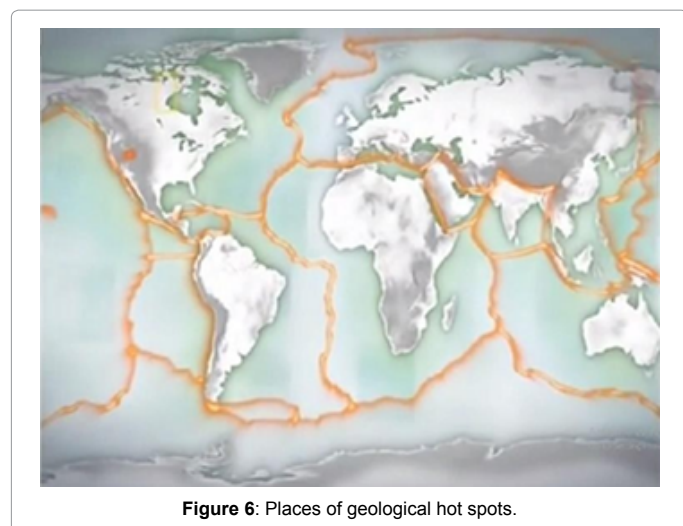
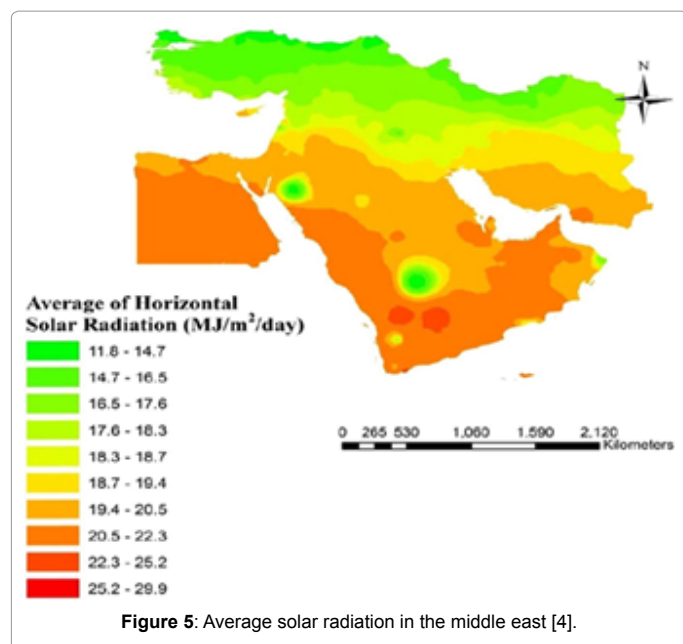
Figure 4: Rotor blade of the 2 MW wind turbine (solid works) [2].

grid) which can be used for small scale power generation. The latter application can be used for rural electrification which is three-fourth of the Yemeni population and only get an amount of one-quarter of the total power in Yemen. It is hard to connect the rural areas to the main grid due to the high cost of transmission and the increased loss of power due to transmission. All these challenges encourage us to demonstrate the high potential of decentralized power demand for rural electrification.

Apparently, if we compare the average solar radiation between Yemen and Iran, we will conclude that Yemen has 200% more radiation than Iran according to the map in Figure 5. Recently, Iran is going to build a 600 MW solar power station funded by the UK. Now, Yemen has to take advantage of the wide uninhabitable areas such as deserts and valleys which are not agricultural to build large solar power satiations to produce electricity. An area of 20 km<sup>2</sup> is capable of producing about 1.5 GW of electricity.

Biomass energy

Throughout the history, Yemen is famous for being an agricultural country, which is the major sector of the country's economy. This agricultural activity will result in a large amount of waste. Also, the waste associated with the industrial activity can harm the environment if it is not treated well to make use of it. All these forms of waste can be utilized



for the sake of biomass potential to be used for many purposes such as gasification for the electricity generation or for the cooking purposes. This technology can be used to make biogas plants in major cities such as Sana'a, Aden, and Taiz, to produce electricity from biogas instead of diesel or heavy fuel (Mazot) used mainly in the diesel power plants in Yemen. For example, if we take the garbage waste that is picked up by the garbage trucks on a daily basis in Sana'a city which occupies more than two millions residents, this will be approximated by 1,000 tons of trash. This trash can be delivered to specialized digesters to produce biogas which is composed of 60% methane (CH<sub>4</sub>) and 40% carbon dioxide (CO<sub>2</sub>). For every ton of waste we estimate to get an amount of 50 m<sup>3</sup> of biogas. So, 1,000 tons of trash will be capable of producing nearly

5,000 m<sup>3</sup> of biogas every day from the garbage in Sana'a. This amount is equivalent to 30,000 KWh. Checking our electric bills, I found that our average use of electricity every day is 5-7 KWh. So, the average use of electricity for a Yemeni house is 6 KWh. Therefore, the amount of electricity produced using biogas energy in Sana'a city alone will power nearly 5,000 houses.

### Geothermal energy

Fortunately, as can be seen from the map in Figure 6 Yemen is among the 10% of the regions in the world which has geological hot spots. The volcanic activity in Yemen is very high which contributes to the presence of high heat flow. This heat flow can be harnessed to produce electricity using superheated water from under the ground. Many geothermal fields in Yemen are readily available for geothermal energy applications. These fields are available in provinces such as Dhamar, Al-Dhala, Ibb, and other coastal areas in the Red Sea and Gulf of Aden. Like Iceland and California where hot water is readily accessible and erupts to the surface, Damt (Al-Dhala) has the same condition. The estimated reservoir temperature ranges between 70-140°C in Dhamar, Ibb, and Al-Dhala. So, in such places it is potentially applicable for geothermal power plants where the surface temperature is around 150°C. It is practically possible to build an overall capacity of 600 MW in such places.

### Conclusion

This research project is aimed to examine the possibility of renewable energy applications in Yemen to produce electricity from clean resources. We need to further investigate our research and deepen our knowledge in these fields to overcome the challenges and bring tangible renewable energy projects into reality in Yemen.

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