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An Assessment of Renewable Energy Potential for Electricity Generation and Meeting Water Shortfall in Pakistan

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Abstract:- It is a widespread reality that sustainable energy supply is one of a key-variable for development of a nation. Pakistan, being a developing country, is confronting the most exceedingly terrible energy crisis that are devastating its socio-economic development. A few steps were taken to meet energy requirements but the strategy couldn't fulfil the demand and supply gap. At present population of Pakistan is increasing at alarming rate. The same trend of energy production from indigenous energy resources will not be able to meet energy requirements of increasing population. The only way for mitigation of these growing energy crisis is to optimally utilize available resources and promote energy production from renewable energy resources instead of relying on nonrenewable resources. Another threat for Pakistan is water drought. It is predicted that by 2025 Pakistan will confront water scarcity if same gravitate of water utilization will be adopted. To meet these water and energy crisis a sustainable integrated strategy is proposed. This proposal not only copes with predicted energy and water crisis but also decrease stress on natural resources. For this purpose, a conspicuous method for fixture of reverse osmosis plant by economizing power factor to reduce process cost has been developed. Energy is produced from wind and solar potential. Energy is produced at an economic rate of 0.06 PKR / KWh along with water production at a rate of 0.06 PKR / gallon. These optimized outcomes will fundamentally assuage the water and energy sector and relieve the general population of Pakistan.

Keywords:- *Renewable Energy; Solar Energy; Wind Energy, Water Scarcity.*

I. INTRODUCTION

In this modern era of industrialization energy is a commodity for survival of life on earth. It plays pivotal role in development of a nation. We get vitality and electric power from different natural and nonrenewable energy source in particular from coal, natural gas, petroleum and its derivative. These natural resources have a constrained accessibility but increasing demand of energy for population is depleting these natural resources at high rate and expelling world, bit by bit, towards serious energy crisis. Due to dereliction management of natural resources world had to face severe energy crisis in 1970s, 1990s and 2000s. In 1970s, industrially developed countries of world such as United State of America, Australia and Japan confronted oil deficiencies and hoisted price of oil. In 1973-74, due to rapid industrialization and increasing population, USA was unable to meet oil demand of country that caused an unexpected increase in oil price. USA was relying on imported oil to meet its national requirements. This increased West Texas Intermediate (WTI) price by 42.6% within last quarter of 1973. In next five years this abrupt increase in oil price was not seen. 1973-74 oil crises were succeeded by energy crisis of 1979-80 and WTI price ascended by 37.5% in April 1980 (Baumeister, C., & Kilian, L., 2016). This series of energy crises shocked the economy of industrial countries and created restlessness. In 1990s, a short energy drought occurred that caused the average monthly oil price of one barrel to increase from $17 to $36 from July to October 1990 (Taylor, J. B., 1993, December). One of the worst energy crises of history occurred in 2003-2008. This crisis is known as energy crisis of 2000s. Before 2000s energy crisis, in 2003, average cost of petroleum was $25 per barrel that increased to $108 per barrel by 2008. Figure 1 describes fluctuation of WTI prices as a function of years.

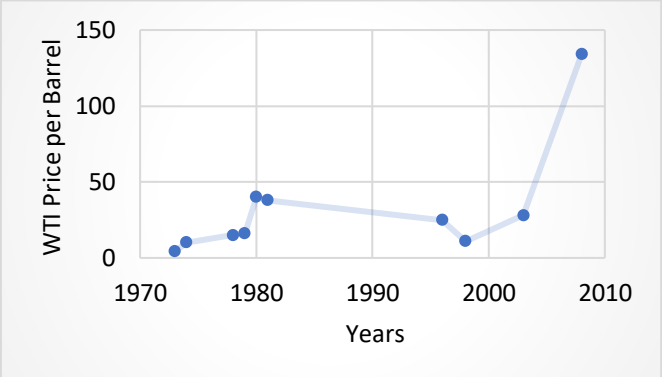

Fig 1:- WTI Oil Price Fluctuation
Source: Journal of Economic Perspectives 30(1)

All above mentioned energy crisis occurred due to complete dependence on natural resources such as oil, coal and natural gas. If alternative renewable energy resources were used in past years world would not face energy crisis of such severity. According to World Bank report (1996), 33% of the

world population is completely dependent on conventional nonrenewable resources of energy production (UNDP, 2004). This caused stress on natural recourses that pushed world toward energy crisis. In spite of facing severe energy crisis in past, still energy production is heavily leaning on fossil fuels, by producing 80% of energy from fossil fuels (IEA, 2011). This level of dependence on natural resources, forecasts exacerbating energy crisis. IEA report (2011), shows that less than 0.8% of total energy is produced from renewable natural resources i.e. wind and solar. From past energy droughts world had not learnt that we should utilize wind and solar potential to produce energy instead of relying on conventional resources. Figure 2 describes contribution of different resources in Energy Production for World in 2009.

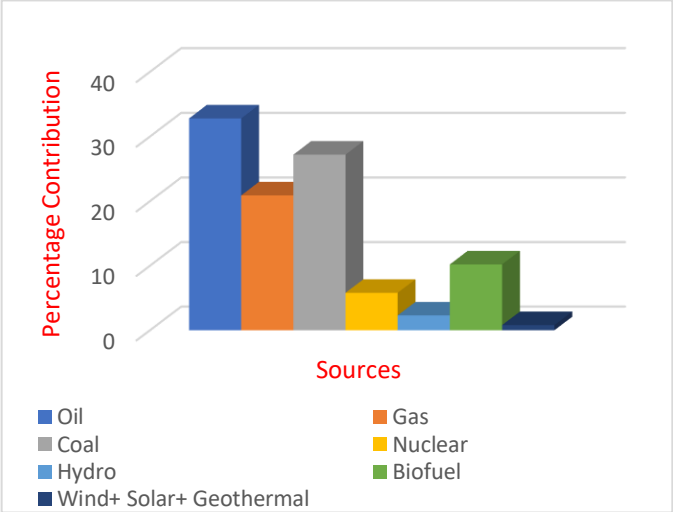

Fig 2:- Contribution of different resources in Energy Production for World in 2009.
Source: International Energy Agency-2011: KEY WORLD ENERGY STATICS

According to research energy production from coal is mentioned as worst method of energy production that contaminates environment and cause adverse effect (Bergeron, L., 2008). In spite of this, world is producing 27% of total energy from coal (IEA, 2011) and contributing to make environment polluted. Figure 3 describes some countries using coal as a major source of electricity production. Instead of using unsafe, conventional and nonrenewable resources, world should utilize wind and solar potential to produce energy because these are safe and renewable energy resources.

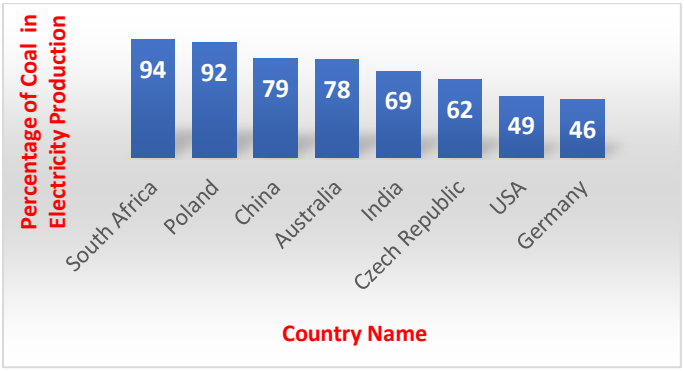

Fig 3:- Contribution of Coal in Electricity Production.
Source: Karl, H. D., & Lippelt, J. (2011).

Another major global issue is water scarcity. Research reveals that about 6.5 % of worlds populace is facing absolute water drought and 52.6% of worlds populace is confronting the same problem for about one month each year (Mekonnen, M. M., & Hoekstra, A. Y., 2016). West Asia and North African countries (WANA) are facing an alarming state of water scarcity. The world's average renewable water supply for each individual is 7000 m^3 per annum but population of WANA countries have supply of only1500 m^3 per person per annum. Among WANA countries Jordan is facing the worst state of water scarcity with supply of only 230 m^3 per annum per head. Current situation of water resources in WANA countries forecasts that about 19 WANA countries will be facing absolute water scarcity by 2025 (El Kharraz, J., et al. 2012). This world is moving towards energy and water crisis due to increasing demand of population with low supply. It is increasing stress on natural resources. The best way to survive in global village is to develop and promote renewable energy resources and alternate water recourses.

II. CASE STUDY AREA

Pakistan is a South Asian country that is considered as case study area. Pakistan is listed at 6th position among all countries of world with respect to its population and at 33rd position with respect to its area. Pakistan is located at GPS coordinates of 30.3753° N, 69.3451° E. Pakistan as has an arid climate with an average rainfall of 53 mm and 212 mm in Kharif and Rabi respectively.

A. Energy Deficit in Pakistan

Electricity sector of Pakistan is dependent on non-renewable resources. Due to improper management and inefficient power plants Pakistan is facing sever energy crisis. In 2008-2009, Pakistan faced electricity short fall of 4025 MW. This shortfall increased to 5529 MW in 2010. (Dar, M. R. et all., 2013). With increasing demand of electricity this shortfall also increased to 7000 MW in 2017(Dawn Newspaper. May8,2017). These energy shortfalls severely affected the economy of Pakistan. A few steps were taken but they could not fulfil the requirements of population. At present only 2% of total electricity production is relied on renewable resources. If Pakistan will not increase reliance on renewable resources and same trend of electricity production will be adopted for future, then Pakistan may have to face energy crisis by 2025. According to Pakistan economic survey (2017-18), current installed capacity of electricity generation is 29,573 MW. To meet requirements of population in 2025, Pakistan has to increase installation capacity by 25,000 MW (About Pakistan., 2017). The best way to meet these increasing requirements of energy is to use wind and solar potential to produce energy. Figure 4 describes Share of Different Resources in Energy Production for Pakistan.

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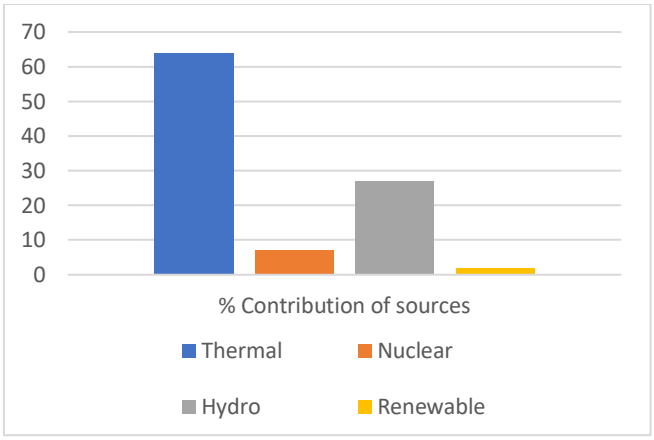

Fig 4:- Share of Different Resources in Energy Production for Pakistan.
Source: Pakistan Economic Survey 2017-18

B. Water Short Fall in Pakistan

To meet water requirements of population, Pakistan greatly relies on Indus River and its tributaries. Other sources of water are ground water and aquifers. Population of Pakistan is increasing at an alarming rate and predicted to be 227 Million by 2025. (GoP., Report 2017 titled *About Pakistan*). But Pakistan's available water resources are only 176.4 MAF (Kahlown, M. A., & Majeed, A., 2003). This implies per capita availability of 958m^3 of water by 2025. That is state of water scarcity. Because according to international standards per capita availability of 1,700m^3 is required to meet water demands of a person, availability of less than 1000m^3 is mentioned as water scarcity, and less than 500m^3 is mentioned as absolute water scarcity (Jenkins, M. W., & Sugden, S., 2006). This inferred that Pakistan will be a water scare country by 2025 with per capita availability of 958m^3. To meet water requirements of Pakistan by 2025 development of alternative water resources is very essential otherwise Pakistan will not have enough water resources to meet demands of population. It is pertinent to mention that Pakistan has agriculture-based economy which is expected to get effected. Table 1 describes the total requirement and water shortfall in detail that may occur by 2025.

Sr.No	Entity	Description
1.	Year	2025
2.	Water Availability	217.588 BCM
3.	Per capita availability	958 m3
4.	Water demand to vanish water scarcity @ 1100 m3 per capita	249.7 BCM
5.	Water demand to meet all requirements @1700 m3 per capita	385.9 BCM
6.	Short fall to vanish scarcity	32.11 BCM
7.	Short fall to meet all requirements	168.3 BCM

Table 1. Water Short fall of water by 2025

III. MATERIALS AND METHODS

This research paper proposed solution to predicted energy and water crisis of Pakistan. Proposal not only meet requirements of population but also decrease stress on natural resources. Proposed plan is environment friendly having no hazardous effects on environment.

A. Proposal to meet Energy Requirements

To cope with forecasted energy crisis a wind park and a solar park along the costal belt of Pakistan is proposed to establish. Complete details are tabulated below.

- *Wind Park*

Pakistan has costal belt of about 1100 km. The area where wind speed is adequate for producing energy is only 1050 km. Out of this 1050, 250 km lies in Sindh province and 800 lies in Baluchistan province (Mazhar H. Baloch. et all.2017). This complete wind zone is engulfed by covering 4 km along width of costal belt that makes total area of wind park equal to 4200 km^2. Joint report of Pakistan Meteorological Department (PMD) and National Renewable Energy Laboratories (USA) shows that average speed of wind at coast of Karachi is about 5.4 ms^{-1} - 6.2 ms^{-1}. As per rule of thumb for wind turbine plant 1km^2 = 5MW. (Mazhar H. Baloch. et all.2017) this implies that electricity production potential of plant will be 5 × 4200 = 21000 MW.

Sr.No	Turbine Name	Specifications
1.	AN Bonus 1000/54	Power: 1000 kW Cut in Speed: 3 ms^{-1} Cut out Speed: 15 ms^{-1} Survival Speed: 60 ms^{-1} Diameter: 54.2 m Swept Area: 2300 m^2 Blades 3
2.	AN Bonus 600/40 MKV	Power: 600 kW Cut in Speed: 5 ms^{-1} Cut out Speed: 15 ms^{-1} Survival Speed: 55 ms^{-1} Diameter: 44 m Swept Area: 1520 m^2 Blades 3

Table 2. Wind Turbine Selection

Table 2 describes the comparison of wind turbines selected for installation. AN Bonus 600/40 MKV is more cost-effective turbine. So, it is preferred for theoretical studies. In wind park distance between two adjacent turbines is kept 5*Diameter = 220 m and distance between two rows is 10*Diameter = 440 m. This implies that 42948 turbines will be install in wind park. The cost information of wind plant installation and maintenance is obtained from different manufactures and analyzed as described.

Production of Wind Plant = 21,000 MW
= 21,000* 24*365
= 183,960 GWh / year

Cost Analysis:

Purchase Cost of Turbines = 1,717.92 Million

Installation Cost = 24,268.8 Million

Cost of Wind Plant =Purchase cost + (Installation Cost)

= (1,717.92 M) + (24,268.8 M)

= 25,986.72 Million

Life span of plant = 20 years

Annual O & M of Wind Plant =20% of total plant cost

= (0.2) (Total cost of plant)

= (0.2) (25,986.72 M)

= 5197.3 Million.

B. Solar Park

Pakistan is one of the favored nations of the world to have rich sun-based asset. Solar energy as a renewable source of energy is broadly, effortlessly exploitable and abundantly accessible in Pakistan. Average annual direct normal solar radiation capacity in Pakistan lies between 4.5 – 5.0. (LEO). This infers that Pakistan has a solar potential of 2,316,077,408 GWh/year (National Renewable Energy Laboratory report, November 25, 2014). In spite of having rich solar energy potential, Pakistan is facing energy crisis. A solar park of area 100 km^2 is to be established at costal belt of Pakistan that covers 50 km along the length of coast with 2 km width. The important factor that effects the output of solar panels is mutual shading which dictates optimum distance between two consecutive solar panels. To optimize the output of a solar park or area available for installation of solar panels only one third should be cover (Quaschning, V., & Hanitsch, R.1998, July). So, the productive land will be only 33.33 km^2 out of 100 Km^2 solar park. For theoretical analysis, solar panel of 4kW capacity is to be install that covers 28 m^2 per panel. This implies that total 2,357,142 number of Solar panels will be installed in Solar park.

Data:

Efficiency = 21%

Solar radiation = 5.5–6 kW h/m^2/day (SBI report)

= 5.75 kW h/m^2/day (average)

Productive Area = 33.33 km^2

Formula:

Production of Solar Plant= Productive area * kWh/m^2/day * 365 days * Efficiency

= 33,330,000 m^2 *5.75 kW h/m^2/day * 365 *0.21

= 14689.78 GWh / year

C. Cost Analysis

Purchase & Installation Cost = 9,4285.68 M

Life span of Solar plant = 20 years

Annual O & M of Solar Plant = 0.8% of total plant cost

= (0.008) (Total cost of plant)

= (0.008) (94,285.68 M)

= 754.2M

D. Per unit Cost of Electricity

Grand Energy Production= Production of Wind Plant + Production of Solar Plant

= 183,960 GWh / year + 14689.78 GWh / year

= 198,649.78 GWh / year

Total Cost of Plants = (Cost of wind plant) + (Cost of Solar Park)

= 25,986.72 M + 94,285.68 M

= 120,272 M

Total O & M of plants= (O & M of wind plant) + (O & M of Solar Park)

= 5197.3 M + 754.2M

= 5951.5 M

Per unit cost = (Total cost of plants / Life span + O&M)/Grand Energy Production

= (120,272 M / 20 + 5951.5 M) / (198,649.78 GWh / year)

= 0.06 PKR / KWh

E. Proposal to meet Water Requirements

To resolve the issue of predicted water scarcity a Sea Water Reverse Osmosis Plant is proposed to install at Karachi sea shore. All calculations are performed for RO plant of capacity 4.97 BCM per annum. Installation of this plant will increase per capita availability to 980 m^3 per capita. To eliminate complete scarcity predicted for 2025, we have to enlarge this reverse osmosis plant by installing same units of 4.97 BCM up to 6 BCM that will provide per capita availability of 1089 m^3 per capita and country confront no water shortage in 2025. This plant may be enlarged further to meet energy requirements of future.

Reverse Osmosis is one of most effective, economic and swiftly growing technique of water purification. The main factors for installing reverse osmosis plant is its energy requirements and its semipermeable membrane cost. This proposed plant will acquire its energy requirements from proposed energy plant. This will reduce the price of per gallon to 0.06 PKR.

Annual Production of RO Plant

Per hour production = 180 million gallons

Working hours in a day = 20

Working hours in a year = (365) (20)

= 7300 hours

Annual Production of Ro Plant= (Per hour production) (Working hours in a year)

= (180 million gallon/hour) (7300 hours)

= 1314000 million gallons

= 4.97 BCM

F. Energy Requirement of RO Plant

In Reverse Osmosis no phase change process take place that make it energy efficient. Energy is required only to pump the water. According to research only 3 – 10 kWh/m^3 of electricity is required for a reverse osmosis plant (Dashtpour, R., & Al-Zubaidy, S. N., 2012). Taking average about 6.5 kWh/m^3 energy is required.

Total Energy Requisite = (Energy for 1m^3) (Annual production)

= (6.5 kWh/m^3) (4.97 Billion m^3)

= 32300 GWh.

This energy is provided to plant from proposed energy plant.

Cost Analysis of RO Plant:-

Purchase cost = 113562 M

Installation Cost = 37854 M

Total cost of RO plant = (Purchase cost) + (Installation Cost)

= (113562 M) + (37854 M)

= 151416 M

Life span of plant = 30 years

Annual O & M of plant = 2% of total plant cost

= (0.02) (Total cost of plant)

= (0.02) (151416 M)

= 3028.32 M

G. Per unit Cost of water

Per unit cost of fresh water=(Total cost of plant / Life span + O&M)/Production

= (151416 M / 30 + 3028.32 M) / 131400 M gallons

= 0.06 PKR / gallon.

IV. CONCLUSION

Pakistan is confronting energy crisis and predicted to have sever energy crisis by 2025. To save Pakistan from these energy crises a wind plant and a solar plant is installed at Karachi sea shore that have a combine energy production of 198,649.78 GWh / year. Out of this total energy 32300 GWh will be utilize to operate Reverse Osmosis Plant. This proposal of energy plant will not only contribute to eradicate energy crisis but also help to conserve limited available energy resource. To meet water requirements RO plant of capacity 4.97 BCM is proposed that produce water at 0.06 PKR / gallon. It is an effective cost of water to supply at a large scale. Both proposed plans are in line with environmental protection policies and promote integrated water resource management and integrated energy resource conservation. Installation of this plant will also contribute to economy of Pakistan. Industries will have proper supply of energy. It will increase their production rate and Pakistan will be on the way of fast development.

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