

Comparison of the Relative Merits of Three Different Sources of Renewable Energy

Naci Kalkan
Bitlis Eren University
Faculty of Engineering and Architecture
Department of Mechanical Engineering, Energy Institute
Bitlis –Turkey
Email: nacikalkan@gmail.com

Abstract -The focus of this study is to compare the relative merits of solar, wind and geothermal, demonstrating that these energy sources are environmentally friendly, cheap and infinite. Additionally, this study describes the similarities and differences among the solar, wind and geothermal energy sources. This report also include analyze the benefits and disadvantages of such renewable sources, comparing these benefits and disadvantages to analyze the effective qualities of each in different situations. Furthermore some statistic data to evaluate the 'practicality' of mentioned sources are demonstrated in more detail.

Keywords: Renewable energy; wind energy; solar energy; geothermal energy; alternative energy sources

I. INTRODUCTION

In the whole world, our energy demand is produced from sources primarily from fossil fuels (natural gas, oil and coal etc.) that are non-renewable and limited in supply. [1] In recent years, the importance of energy sources has risen around the world as a result of an increasing population. Although there are many energy sources, the amounts of fossil fuels such as oil and natural gas have decreased sharply [2] (Figure 1). At that point, there is a renewable energy which is produced from natural sources like solar, wind, geothermal, wave and tidal energy. The negative impacts of renewable energy sources

on the environment are less than fossil fuel ones and the cost is much more expensive

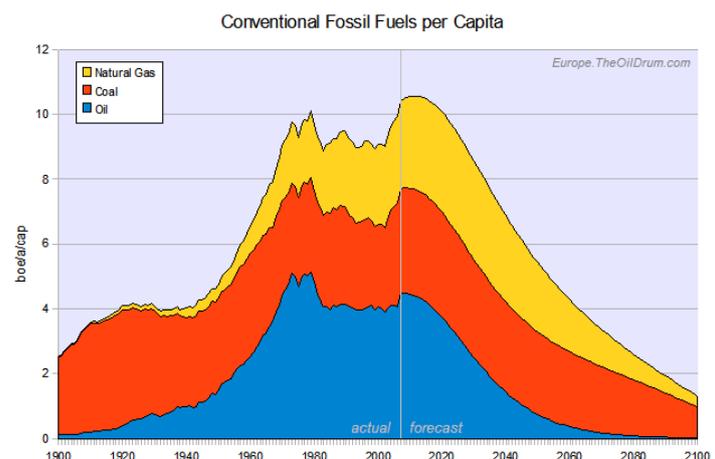


Fig.1. Forecast for Conventional Fossil Fuels per Capita [3]

II. SOLAR ENERGY

Solar energy is the largest energy source in the world and it is an indispensable source for living organisms and environment. Currently, many systems are used to provide benefit from the sun. Some of them are solar collector, solar space heating, and solar hot water heating and solar electricity (Figure 3). Gathering maximum solar energy depends on the season of the year, on the time of the day and weather [4].



Fig. 2. Liquid-Based Solar Heating System, [5]

III. WIND ENERGY

Wind energy is one of the world's fastest-growing sources energy presently. In last decade, wind energy growth rates are approximately 30% annually around the world [6]. In the past, wind was used to sail ships and pump water from well. Nevertheless, wind power has been used to generate electricity by using the wind turbine recently (Figure 3). Generally, wind turbines convert wind into electrical energy. Although wind power system seems to be like a complex construction, first investment's cost is not too much [7].

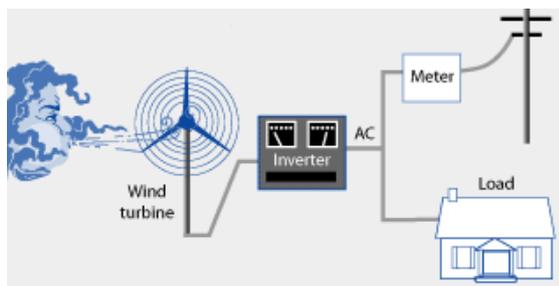


Fig. 3. Grid Connected System , [8]

IV. GEOTHERMAL ENERGY

Geothermal energy might be generated by making a huge hole into the Earth crust with pumping cold water via one and later as time pass it raises back to the surface and water will be very hot and then it will be used as a steam to push a turbine that drives a power creating generator. This process shows that hot underground water, which comes from rainfall and heating is provided continuously deep

within the earth, is tried to surface. Hence, geothermal energy can be named renewable energy source. Before 1904, geothermal energy can be used only for heating and bathing, but now using this source to produce electricity in a new industry [4].

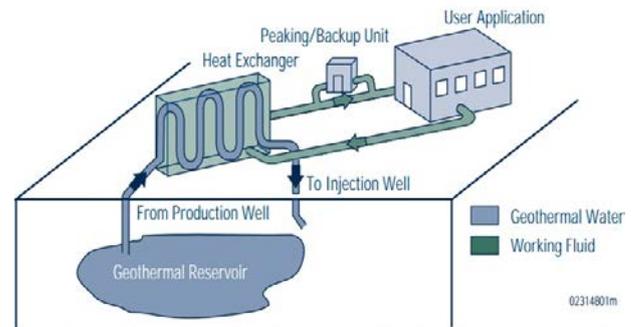


Fig. 4. Geothermal Energy Overview [9].

V. COMPARISON OF THE SOLAR, WIND AND GEOTHERMAL ENERGY

Each of this renewable Energy has its own set of unique benefits and drawbacks. A closer investigation of them can mark some similarities and differences between the solar and wind. For instance, while solar energy provides its power from the sun, wind energy utilizes from wind to gather wind power and convert to electrical power. Although at first glance solar and wind energy systems provide their power from two different sources, there are some similarities. For example, both solar and wind generators make use of a battery system in order to store gathered energy. When panel or turbine, which is then converted into electrical energy, collect the sunlight or wind powers, electricity is deposited within a battery. In addition, solar and wind energy does not create emission such as poisoned gases for ozone layer, so these are clean energy sources. These also provide cheap electrical power because of using natural situations. On the other hand, there are some differences between these two sources; for example, while maximum benefit from wind can be utilized in the fall and winter in the wind days, solar power is at its best in the summer where there are a lot of bright sunny days. The other side of using wind turbines is it may cause the noise pollution from commercial

wind turbines if nobody lives in neighborhood area there is no problem but if there are any people who live close the turbines it may cause some problems. Although solar collector works silently, it might cause visual pollution on the roofs [10].

Unlike solar and wind, generating electricity from geothermal has shown different method that starts after the heat source discovered. One turbine, which is forced by large steam, is located under the land. This turbine is also linked with generator. When steam makes turbine turn speedily, turbine causes to rotation of generator and ultimately electricity is generated. This process also depends on location and conditions; for instance, although this process is difficult but is done similarly, geothermal energy produces only a small percentage of U.S. electricity because U.S. is not suitable for geothermal. In other words, approximately 15 billion kilowatt-hours or 1% of the total electricity comes from geothermal energy in the U.S. [4]. However, geothermal plant is so friendly for environment because these plants do not have transport fuel and this one has been built in mountain forests or deserts. Also there is no emission because they do not burn anything during the generating electricity. One of the most important differences from solar and wind for geothermal energy extraction is that in many situations, a site that extracts steam and generates power and energy may immediately stop generating steam. However, it might happen at approximately 10 years in some situations. Moreover, because of being extracted from deep within the surface of the Earth it is too difficult to find a suitable construction area and it is a big disadvantage [11].

VI. STATISTICS

In the last two years, 8% of world energy consumption comes from renewable energy sources and currently, this rate has increased rapidly. Indeed, renewable electricity capacity has risen by 9,376 megawatts from 2008 to 2009 and the majority of this increase was provided with wind energy which climbed 95% of increase in a year. Nevertheless, there are

smaller contributions from geothermal and solar energy that's total capacity is approximately 2000 MW in a year [12] (Figure 5). Furthermore, renewable energy policy network for the 21st century offers some statistics about these sources' price; for instance, a normal wind turbine, that's capacity is 3 MW, consumes 6 cents in an hour and for geothermal this point is about 5 cents. Normally, solar energy is free, so there is not any payment during using the sunshine [13]. When these statistics compare with petrol prices, it is clear that the renewable energy sources need much more attention.

(Quadrillion Btu)					
Energy Source ¹	2005	2006	2007	2008	2009
Total	100.468	99.790	101.502	99.438	94.820
Fossil Fuels	85.815	84.687	86.223	83.532	78.631
Coal	22.797	22.447	22.749	22.398	19.996
Coal Coke Net Imports	0.045	0.061	0.025	0.040	-0.023
Natural Gas ²	22.583	22.224	23.679	23.814	23.416
Petroleum ³	40.391	39.955	39.769	37.279	35.242
Electricity Net Imports	0.084	0.063	0.106	0.113	0.116
Nuclear Electric Power	8.161	8.215	8.455	8.427	8.338
Renewable Energy	6.407	6.825	6.719	7.367	7.745
Biomass ⁴	3.117	3.277	3.503	3.852	3.884
Biofuels	0.577	0.771	0.991	1.372	1.546
Waste	0.403	0.397	0.413	0.436	0.447
Wood and Derived Fuels	2.136	2.109	2.098	2.044	1.891
Geothermal Energy	0.343	0.343	0.349	0.360	0.373
Hydroelectric Conventional	2.703	2.869	2.446	2.512	2.682
Solar Thermal/PV Energy	0.066	0.072	0.081	0.097	0.109
Wind Energy	0.178	0.264	0.341	0.546	0.697

Fig. 5. Energy Sources Capacity [12]

VII. CONCLUSION

With this study many descriptions, examples, analysis and statistics are explained to identify what solar, wind and geothermal energy sources are. The main advantages of such renewable energy sources [1].

- Save CO₂ emissions.
- Proven and reliable.
- Save heating/cooling bills.
- Rapid growth technology (available all over Europe).
- Reduce the dependency on imported fuels.
- Save rare natural sources.

It can be clearly seen that these sources depend on different special conditions to gain maximum benefits such as windy or sunny day. Moreover, solar and wind energy usually keeps close each other such as same structure of their system. In addition, all three sources are not only environmentally friendly when generating energy but also provide to save our bill with their lower costs.

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