Renewable energy resources - an analysis from the Rocky Mountains

Aun Hassan
Colorado State University Pueblo

ABSTRACT

"Americans believe in climate change risks but won't pay to fix them (Goldenberg, 2013)." A recent Stanford University survey revealed this contradiction. The environmental impact of recent disasters; Hurricane Katrina and BP Oil spill have made Americans more interested in this topic. According to the survey, more than 80% of the respondents believe in climate change out of which around 70% feel that these climate changes are the cause of damaging storms and the alarming rise in the sea-level. Considering the high impact of traditional sources of energy on the environment, the paper examines the cost-effectiveness of a conventional power plant vs. building and operating a renewable energy plant in the State of Colorado which is rich in natural resources like wind and solar.

Keywords: Renewable Energy, Solar, Geothermal, Wind, Photovoltaic

INTRODUCTION

The electricity generation was 60% from coal and 22% from natural gas with only 18% generated from renewable energy sources in the state of Colorado in 2014 according to the US Energy Information Administration (EIA), 2015. The process of generating energy from coal requires burning of fossil fuels which cannot be reused. The bed of coal or coal seams take hundreds of years to build up to a level thick enough for mining. The generation of artificial fossil fuels is a slow and costly process. Coal, therefore, cannot be categorized as a renewable energy source and neither natural gas. According to the United States Environmental Protecting Agency (EPA, 2013), any sources of energy that restore themselves over a short period of time can be categoprized as reneable energy sources. Some of the sources of renewable energy include sun, wind, geothermic, biogas, and hydroelectric which have a much smaller impact on the environment compared to the traditional sources of energy. Some of the negative impacts of these renewable energy sources include the impact of hydroelectric power plants on the breeding habits of fish and the altering effect of the ecosystem by wind turbines. Still, the negative impact of these renewable energy sources on the environment is far less devastating compared to the energy production from fossil fuels. This paper describes the cost and benefit of five different types of renewable energy sources namely solar, wind, hydroelectric power, geothermal, and biomass.

Solar energy is the power generated using sunlight and can be either used to transform directly into electricity through a chemical process involving semiconductors or the sunlight can be used to heat water via solar panels. According to the Solar Thermal Alliance of Colorado, the Centennial state lies in the “bull’s eye” of solar energy generation (2012). Colorado gets more than three hundred days of sun every year and with these abundant hours of sun and a great demand for electricity and heating due to rapidly changing temperatures, Colorado becomes the ideal place for solar power generation. Studies by the National Renewable Energy Laboratory (NREL) and the Florida Solar Energy Center (FSEC) confirm this solar efficiency, reporting that Colorado performs better in solar energy than any other state in the U.S. (Merrigan & Parker, 2010.) Citizens of Colorado passed Amendment 37 in 2004 which based on which the state has to produce around 2.5 GW of renewable energy. Therefore, the local utility companies are expected to be generating about 30% of their energy from renewable energy sources by the year 2020 (Jaffe, 2012.) Most utility companies on the state are using both solar and wind power to fulfill this goal, which are essentially the two major types of renewable energy sources in the rocky mountain region.

Wind constitutes another significant source of renewable energy in Colorado. According to the American Wind Energy Association, Colorado produced close to 14% of its total energy through wind power. The geographical location of Colorado allows for above average wind speeds and as the wind turbines are mostly installed in the non-urban regions, the benefits of clean energy are gained without disturbing urban areas. However, the weather in Colorado can change rather quickly and remains inconsistent which leads to a highly unstable energy generation. Storage of this energy is also quite costly resulting in wind being considered as not a reliable source of renewable energy for the economy. However, wind energy can still be used as a supplemental source of energy. Another clean source of energy is hydroelectric power where electricity is generated through water. Water is stored in dams and barrages and then released to create a fall. These falling waters result in spinning the turbines which generate electricity. Although hydro power only contributes about 1.3% of the total energy, it still makes it the second highest source of renewable energy in Colorado (EIA, 2012). There has been slow to nonexistent growth in this hydropower sector due to the unavailability of proper places to create dams for storing water, creating waterfalls.

Geothermal energy refers to the heat that comes from the interior of the earth. Seismic adjustments cause changes in the earth's crust and let magma and steam rise closer to the surface heating the ground and groundwater around it. This heat can be used either directly or to produce electricity using turbines. The existence of geothermal potential becomes visible when one takes a look at the close to sixty hot springs in Colorado where the naturally heated water is used for recreational and wellness purposes. Unfortunately, there are no commercial power plants for geothermal energy in Colorado and therefore the potential of this power source has not been discovered (the GeoPowering the West Colorado State Working Group, 2007). Geothermal energy is included as one of energy sources in this discussion since Colorado has abundance of this resource.

Biomass refers to dead plants found in the earth. Wood is considered the most common biomass i.e. dead trees, loose branches, tree stumps and wood chips. They can all be burned to power steam turbines and generate electricity. Yard clippings, fallen leaves and municipal waste can also be converted into energy. In Colorado, a program was put into action in 2012 in which biomass is regularly collected from the San Juan National Forest to create better forest health. Biomass can be used to generate about 5MW (Mega Watt) of energy (Geiver, 2012). In the same year the city Gypsum approved the building of a biomass plant which would produce cleaner energy for the region (Franz, 2012.) There are enough national forests in Colorado therefore biomass can be used as a vital source of energy. The removal of dead plants and trees from the forests also lowers the risk of fires in the region.

LITERATURE REVIEW

Chang and Li (2015) have also studied the impact of renewable energy production on a set of different economies. Around 50% of the energy production comes from coal in the United States as the US holds about one fourth of the coal deposits in the world, it is quite independent in the production and use of coal (Lerche & Media, 2012). These deposits are expected to last for several decades keeping prices low and providing work in the U.S. (EPA, 2007). There are however, some downsides of generating energy using the traditional method. Lerche and Media (2012) list water pollution, due to the large quantity of water needed for the coal production and air pollution, since coal produces more toxic fumes while burned than any other fuel source. In addition, they state that mining for coal alters the local ecosystem by introducing roads, clearing trees and removing large sections of land. The Bureau of Labor Statistics counted in average almost six times as many fatal injuries in coal mining than in the average of the private industry leading 31 days absenteeism of work in the mines compared to 8 days in the whole private industry (BLS, 2010). An investment plan in renewable energy plants is developed by Ding and Somani (2008) to show the benefits of replacing the shrinking common fossil energy sources. Brandt, DaSilva and Ferreira (2005) studied the feasibility of setting up a 126 MW wind farm in north-east Venezuela and concluded that it is not a cost efficient option without a support from the government. Akuru and Okoro (2010) describe how the installation of a large wind park, solar photovoltaic, solar thermal plants, and some small hydro and biomass power plants contribute to an efficient and reliable mix of energy resources in Nigeria. Chen et al. (2014) have discussed the importance of renewable energy resources in three major economies; Japan, South Korea, and Taiwan who are deficient in fossil fuels.

Geißler (2013) has compared the US and Germany in terms renewable energy policies and production and describes how the US seems to be leading in this field. Kirsten (2014) discusses how Germany has improved the use and production of renewable energy over the past decade through promotions and incentives. Li et al. (2015) have suggested that landfill maybe used to generate energy as well that would lower the greenhouse gases. Ahmad Zahedi (2004) refers to the challenge of transporting renewable energy to remote areas requiring better overall infrastructure. Balasubramanian, Cellatoglu and Yasli (2012) found in their research that the green energy is generally consumed in the production region itself. This is essential for the analyses at hand as for Colorado, the high cost of transporting and distributing renewable energy will not be a part of the equation but just the set-up, operating, and maintaining costs will be compared. Jenner et al. (2012) studied the effect of government subsidies on establishing renewable energy power plants. The paper emphasizes how subsidies act as a great incentive towards renewable energy investment for individual investors which should result in a better outcome for the community and the overall economy.

DATA

The data was obtained from the U.S. Energy Information Administration where the values given in Table 1 (appendix) refer to the original data values. The following table; Table 2 shows the calculated values including the depreciation over the life of the plants as well as the value of technology. According to Sachs, Russel, Rogers, & Nadel (2012) a typical power plant depresciates at an annual rate of 3.3% so that was the rate used by the paper in the calculations. The paper uses the data values to compare the cost and benefit of the conventional and reneable energy power plants. Both fixed and variable costs along with the cost of maintenance is included in the analyses. These costs are compared between the renewable energy plants to the existing coal and biogas plants over a period of one year.

EMPIRICAL ANALYSIS

The analysis involved a comparison of operation and maintenance costs. The operating costs are abbreviated as TOC, the variable costs involving costs on raw materials and general maintenance are abbreviated as VOC and the fixed costs such as depreciation over time are abbreviated as FOC. The simple relationship between the costs is given as:

$$TOC = VOC + FOC \quad \text{(i)}$$

Table3 (Appendix) shows that running a power plant for biomass, geothermal, or solar energy is not cost effective and better technology is needed to make them more cost effective. Wind, photovoltaic and hydro-electric seem to be more competitive to that of coal and natural gas even though natural gas production costs are quite low in Colorado. The future savings of establishing these renewable energy plants are subtracted from the initial investments of building these plants to determine the overnight costs. The renewable energy plants must be generating the same level of output as the traditional plants for them to be considered a replacement. The overnight costs of an average coal or natural gas power plant which typically generates 500,000 MW per year are used as the basis for comparison. The set up cost for a 500,000 MW unit are given in Table 4 (Appendix.) The annual operating and maintenance costs of different plants were calculated at the basis of 500,000 MW per year as shown in Table 5 (Appendix.) Table 6 (Appendix) describes the cost difference between different types of plants. Finally the time needed to amortize the building of the new plants is determined by dividing the overnight cost for the plant (OC) by the annual cost savings (CS). The "payback period" of renewable energy plants is described in Tables 7 and 9 (Appendix.) The payback period refers to the number of years after the initial investment of the overnight cost when the savings equal the overnight costs.

$$\text{Payback Period} = OC/CS \tag{ii}$$

The results describe that it will take more than a typical lifetime to reap the benefits of investing in a renewable energy plant and that is why coal and natural gas still generate about 86% of the energy in Colorado. Wind or solar plants would take about 200 years to show a positive return on investment. Although the traditional coal and natural gas plants cost more on yearly basis of operation compared to the renewable energy plants yet the yearly future savings will take a very long time to offset the higher initial costs to establish renewable energy plants. Some stakeholders suggest that there are other factors that should be considered when comparing the traditional and renewable energy power plants. Pollution being one of those factors and the health risks associated with the use of traditional power generation somehow justifies the additional costs. The paper therefore attempts to incorporate the costs of pollution into the analysis.

Table 8 (Appendix) describes the operating and maintaining costs including the cost of air pollution. The U.S. Environmental Protection Agency (EPA) calculated the costs that arise from breathing polluted air and the connected costs for doctors' visits, decreased property values, and pollution-related deaths. According to "The Cost Of Polluted Air Could Run To Trillions Of Dollars" the estimated cost associated with these factors is $1.3 trillion per year (2012). Based upon the proportional size of population in Colorado, the cost of pollution can be estimated at around $20.8 billion for Colorado. According to a report by EIA (2012) there are 13 coal and 26 natural gas power plants located in Colorado. The paper distributes this cost over the total number of plants equally and so the average cost of pollution per plant can be estimated at $53.33 million. The costs and the payback period are then recalculated including the cost of pollution. The payback period decreases significantly after the pollution costs are added to the analysis making it possible for an investor to reap the benefits of their investment during their lifetime.

Based upon the empirical analysis, the paper finds that it may not be worthwhile for individual investors to consider investing in renewable energy power plants as the potential returns could take more than a lifetime to appear. However, in terms of the benefits to the society and the economy, the benefits go beyond just the monetary returns on the renewable energy plants. These benefits appear in the form of a decrease in environmental pollution which results in better quality of air for the habitat and lower medical costs associated with illnesses that may be caused by pollution. Incorporating these costs makes investing in renewable energy power plants a no-brainer.

CONCLUSION

The paper attempts to compare the benefits and costs of installing new and modern renewable energy power plants in the state of Colorado to replace the existing traditional coal and natural gas based power plants. The paper finds that the renewable energy plants of the types; wind, hydro, and solar are very cost competitive to the traditional power plants with the added bonus of low emissions to the environment. The high initial investment in these modern plants may cause an initial setback but the overall value of installing these plants is definitely much greater than the initial costs. There are tremendous benefits to the society and to the natural habitat which may be worth all the cost. The study also suggests that the government needs to play an active role in this industry and to promote this modern technology; the government should provide subsidies and tax incentives to investors. The government may also bring more awareness to the society by promoting this idea via social media. The paper concludes by suggesting that more research needs to be done to study the renewable energy sector and that greater collaboration is needed from researchers and economies with the US and around the world to explore the potential benefits in this industry.

OTHER THOUGHTS

The paper faces certain limitations in terms of the available data and analysis performed. The study assumes that technology remains the same over the period of the calculation i.e. the lifetime of a power plant. The analysis depends upon the costs of pollution estimates provided by EPA but it is difficult to determine the validity of these estimates hence a different set of numbers could significantly change the results of this paper. The cost of pollution is imposed solely on the existing power plants assuming that the pollution in the state is being caused by these plants only which is once again a strong assumption but is a necessary step to make it possible to complete the analysis. Another limitation is that the cost for air pollution is distributed over the conventional power plants in Colorado. The paper however makes some recommendations; if the state and federal governments offered significant subsidies and or tax incentives, then perhaps more investors would be inclined towards investing in these renewable energy projects. As investments increase, the demand for the equipment and technology required for establishing these energy plants will go up resulting in a positive externality on the production sector. The paper also finds that there is a lack of research and perhaps interest on the topic and more research collaboration is necessary to further understand the problems associated with this industry.

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APPENDIX

Table1: Annual Capital Cost Estimates for Electricity Generation Plants

	Plant Output	Plant Input		
	Nominal Capacity (kilowatts)	Overnight Capital Cost[1] ($/kw)	Fixed O&M Cost ($/kw)	Variable O&M Cost ($/kw)
Coal				
Single Unit	650,000	$3,167	$35.97	$4.25
Dual Unit	1,300,000	$2,844	$29.67	$4.25
Natural Gas				
Conventional Unit	540,000	$978	$14.39	3.43
Advanced Unit	400,000	$1,003	$14.62	$3.11
Biomass				
Biomass CC	20,000	$7,894	$338.79	$16.64
Biomass BFB	50,000	$3,860	$100.50	$5.00
Wind				
Onshore Wind	100,000	$2,438	$28.07	$0.00
Solar				
Solar Thermal	100,000	$4,692	$64.00	$0.00
Photovoltaic	150,000	$4,755	$16.70	$0.00
Geothermal				
Binary	50,000	$4,141	$84.27	$9.64
Hydro				
Hydro-Electric	500,000	$3,076	$13.44	$0.00

Table 2: Updated Annual Capital Cost Estimates for Electricity Generation Plants

	Plant Output	Plant Input		
	Nominal Capacity (kilowatts)	Overnight Capital Cost ($/kw)	Fixed O&M Cost ($/kw)	Variable O&M Cost ($/kw)
Coal				
Single Unit	650,000	$3,167	$37.17	$4.39
Dual Unit	1,300,000	$2,844	$30.66	$4.39
Natural Gas				
Conventional Unit	540,000	$978	$14.87	3.54319
Advanced Unit	400,000	$1,003	$15.11	$3.21

Table 3: Total Operating and Maintaining Cost per KW

Coal	Single Unit	Dual Unit	Natural gas	Conventional Unit	Advanced Unit	Biomass	Biomass CC	Biomass BFB
	$41.56	$35.05		$18.41	$18.32		$355.43	$105.50

[1]Cost for building a new power plant

Wind	Onshore Wind	Solar	Solar Thermal	Photovoltai c	Geothermal	Binary	Hydro	Hydro-Electric
	$28.07		$64.00	$16.70		$93.91		$13.44

Table 4: Set up cost per 500,000 MW

Onshore Wind		Photovoltaic		Hydro-Electric
$1,219,000,000		$2,377,500,000		$1,538,000,000

Table 5: Operating and Maintaining Cost per 500,000 MW per Year

Coal Single Unit	$20,779,663.00
Coal Dual Unit	$17,524,768.00
Natural Gas Conventional Unit	$9,206,188.50
Natural Gas Advanced Unit	$9,160,204.50
Onshore Wind	$14,035,000.00
Photovoltaic	$8,350,000.00
Hydro-Electric	$6,720,000.00

Table 6: Operating and Maintaining Cost Differences at the Basis of 500,000 MW

	Coal Single Unit	Coal Dual Unit	Natural Gas Conventional Unit	Natural Gas Advanced Unit	Onshore Wind	Photovoltaic	Hydro-Electric
Coal Single Unit	---	3,254,895	11,573,475	11,619,459	6,744,663	12,429,663	14,059,663
Coal Dual Unit	-3,254,895	---	8,318,580	8,364,564	3,489,768	9,174,768	10,804,768
Natural Gas Conventional Unit	-11,573,475	-8,318,580	---	45,984	-4,828,812	856,189	2,486,189
Natural Gas Advanced Unit	-11,619,459	-8,364,564	-45,984	---	-4,874,796	810,205	2,440,205
Onshore Wind	-6,744,663	-3,489,768	4,828,812	4,874,796	---	5,685,000	7,315,000
Photovoltaic	-12,429,663	-9,174,768	-856,189	-810,205	-5,685,000	---	1,630,000
Hydro-Electric	-14,059,663	-10,804,768	-2,486,189	-2,440,205	-7,315,000	-1,630,000	---

Table 7: Payback Period of new Renewable Energy Plants

	Onshore Wind	Photovoltaic	Hydro-Electric
Coal Single Unit	181	191	109
Coal Dual Unit	349	259	142

Natural Gas Conventional Unit	---	2777	619
Natural Gas Advanced Unit	---	2934	630

Table 8: Operating and Maintaining Cost Including the Cost of Air Pollution

Coal Single Unit	$74,109,663.00
Coal Dual Unit	$70,854,768.00
Natural Gas Conventional Unit	$62,536,188.50
Natural Gas Advanced Unit	$62,490,204.50
Onshore Wind	$14,035,000.00
Photovoltaic	$8,350,000.00
Hydro-Electric	$6,720,000.00

Table 9: Payback Period of new Renewable Energy Plants

	Onshore Wind	Photovoltaic	Hydro-Electric
Coal Single Unit	20	36	23
Coal Dual Unit	21	38	24
Natural Gas Conventional Unit	25	44	28
Natural Gas Advanced Unit	25	44	28