Techno Commercial Feasibility Study of Renewable Energies

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Abstract - *The global energy demand is going to increase substantially in the upcoming decades, and this energy demand can not be fulfilled by the conventional energy sources because of its depleting nature. Hence there is a global search for the next reliable source of energy. For a long time nuclear energy was the center of attention for this search for a constant, long term energy source, but the risks and disasters associated with it diverted the search towards the renewable energies. The global concern of climate change has led to application of lot of policies to reduce the carbon emission to curb the global environmental crisis. By replacing conventional power sources with renewable energy sources it is possible to enhance energy efficiency and reduce carbon footprint. In this paper, we are going to compare commercial aspects of major renewable energy sources, their carbon emission and feasibility based on the terrain.*

Key Words: Renewable energy, Wind Energy, Solar Energy, Biomass Energy, Hydro Power, Tidal Energy.

1. INTRODUCTION

Renewable energy is energy that is collected from natural sources which are naturally replenished on a human timescale. Renewable Energy Power capacity increased from 1140 GWe in 2008 to 2378 GWe in 2018, this data shows the upward growth trend of the renewable energy sector. As of 2018, 169 countries have policy targets for renewable energy use, hence it is imperative for us to know about the major renewable energy sources and their commercial applications to meet with the growing demands of the sector. There are three primary motivators that stimulate the growth of renewable energy: Energy security, economic impacts and carbon dioxide emission reduction. Renewable energy markets are not easily formed because of cost disadvantages and subsidizing of fossil fuels, that is why this paper gives a comprehensive study of cost of adapting various forms of energy(economic impact), their global potential(energy security), their environmental impact (carbon emission reduction) and selecting a type of energy production based on terrain & geographical conditions of the place. The goal is to make it easier for policymakers and businesses to assess the environmental trade offs and economic viability of investing in renewable energy plants.

1.1 Hydro power

To produce electricity, a high rise dam is built to stop flowing river water. This creates a reservoir behind the dam, the potential energy of the water in reservoir is converted into kinetic energy to turn the turbines which is coupled with generators. This rotation of turbines produce electricity. Hydro power is the world's top provider of renewable energy, producing a whopping 16 per cent of the global energy supply. That's a good thing when it comes to the climate, especially compared to energy from fossil fuels. But hydro power is not without its environmental costs, one of the potential environmental effects of hydro power development is what it can do to biodiversity. It can alter fresh water habitat, degrade water quality, and change land use by flooding land for reservoirs, and from construction of dam and the power lines. Hydro power has caused problems for local residents associated with the need to relocate. On the other hand hydro power energy is attractive because of the preexisting supply of water for irrigation, industrial and household use. Hydro power is clean energy that allows us to store power as well as water.

1.2 Wind Energy

Moving air is called wind. Wind is a by product of the thermal energy received by the earth from sun. The uneven distribution of solar energy gives rise to uneven potential across the globe. Air when heated rises up, giving rise to a low pressure zone, the air from surrounding high pressure zone rushes in to create an even potential. This movement of air causes wind. This wind carries a lot of kinetic energy, which when tapped properly can turn turbines (windmill) which in turn power the generators that produces electricity. Although wind energy doesn't produce any kind of pollution but setting up a wind farm is expensive and requires a lot of land. The installed capacity of wind power has increased from 4.8 MW in 1995 to more than 239 GW in 2011. Today, each wind turbine can generate as much electricity as a conventional power plant.

1.3 Tidal Energy

Tidal energy is one of the oldest forms of energy used by humans. Tidal energy date back to 787 AD. Tidal power is non polluting, reliable and predictable. Tidal barrages allow tidal waters to fill an estuary via sluices and to empty through turbines -like wind turbines but driven by the sea. The rotation of turbines powers the generators that produces electricity. Unlike wind and waves, tidal currents are entirely predictable.

1.4 Solar Energy

Solar energy is the energy obtained by capturing heat and light from the sun. Active solar energy techniques includes the use of photovoltaic cells, concentrated solar solar power and solar water heating to harness the energy. Solar photovoltaic cells generate electricity by absorbing sunlight and using the light to create electricity. The solar photovoltaic market has experienced extraordinary growth. The market has increased from 9,564 MW in 2007 to 69,371 MW in 2011. Similar to wind energy, solar energy is dependent on weather conditions. Variation in weather, including clouds and pollution could affect solar power generation. Moreover solar power has time limitations. Therefore solar power generation varies by season, location and day time.

1.5 Biomass Energy

Biomass is plant or animal material used for energy production. It uses wood or forest residues, waste from food crops, horticulture, food processing, animal farming or human waste as its fuel. When burned, energy from biomass is released as heat, this heat is used to produce steam that in turn rotates the turbine to produce electricity. As the biomass is waste product from by various other industries it will always be there, hence the fuel is omnipresent.

2. RENEWABLE ENERGY GROWTH STIMULATOR

2.1 Energy Security

Concerns about the security of the energy supply were raised after the Arab oil Embargo in 1973. Additional factors include high oil prices, the increasing dependency on oil imports, depletion of fossil fuels, political instability in major oil producing areas and a high impact due to any disruption in energy supply in developed and developing countries. For coal also, the limited quantity of the natural resource and the fast consumption rate increases the global concern for energy security. For these reasons renewable energy seems like an attractive option, but it should be noted that renewable energies themselves are not completely free of these energy security concerns. A result of intermittent characteristics for some energy types including solar and wind energy, as well as possibility of low rainfall for hydro power consumption.

Still the global potential for renewable energy is huge. According to M.K Hubbert, the world is set to run out of fossil fuels in the next 50 to 100 years. So it is important to know the alternative options in energy we have and their respective global potentials, here is a list of major renewable energies and their global potential:

Table 1: Global Potential

Solar Energy	3.9*10^18 KWh
Wind Energy	3.4*10^11 KWh
Bio Mass	8.33*10^14 KWh
Hydro Power	128*10^12 KWh
Tidal Energy	3*10^9 KWh

The following figure shows the total annual energy available, conventional and renewable, with respect to the annual global demand:

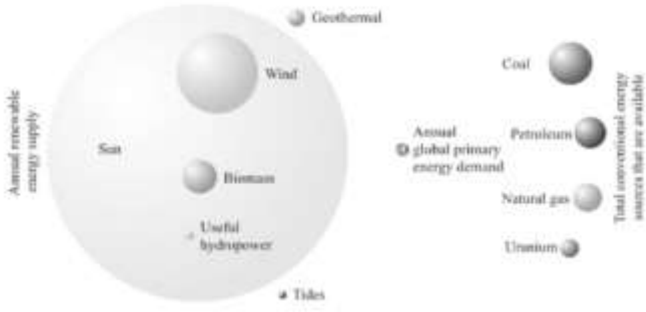

Fig 1

Total available global potential is not converted to useful energy, the ratio of useful energy to energy input is called efficiency.

Efficiency=useful energy produced/ energy input

Wind Energy	35-45%
Solar Energy	15-18%
Biomass Energy	75-80%
Hydro Energy	90%
Tidal Energy	19%
Coal Energy	37-50%

Table 2: Energy Efficiency

Wind efficiency is the amount of kinetic energy in the wind that is converted into mechanical energy and electricity. The laws of physics described by Betz Limit says that the maximum theoretical limit is 59.6%. The wind requires the rest of energy to blow past the blades. It is, however not possible for any machine at present to convert all of it's 59.6% of kinetic energy from wind to energy. The average at present is 35% to 45%

There are three stages of energy based on its form:

Term	Definition	Energy type or source
Primary energy	Energy in its original form, not technically processed	Such as crude oil, coal, uranium, solar radiation, and wind
Final energy	Energy as provided to consumers	Such as natural gas, heating oil, fuel, electricity, and district heat
Useful energy	Energy as it is consumed	Such as artificial lighting, heat, drive energy for machines and vehicles

The following figure shows the distribution and dissipation of energy in various stages:

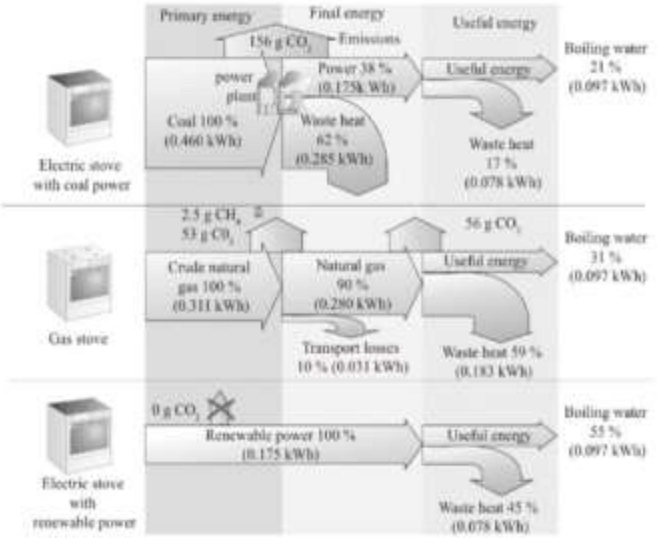

Fig 2

2.2 Economic impacts

The importance of economic impacts are job creation, industrial innovation and balance of payment. Renewable energy can enable countries with good wind and solar potential to employ them to meet there domestic demand. Furthermore these countries can plan to export the power generated from these sources to other countries and earn revenue in return. According to IEA cost benefit analysis, 103 trillion dollars will be saved during the years 2010-2050 by reducing fossil fuel consumption. A main economic driver to the enhancement of renewable energy technology is their job creation potential.

For any commercial project to be feasible, it is important to know the different kinds of costs associated with it. For any power plant the most important thing to know in terms of capital investment are: levelised cost of energy (LCOE), cost of installation, operation and maintenance cost (O&M), and the land use requirement. Other than this it is also important to know the expected life of a power plant. After considering all these factors only can one decide if a particular type of power plant is commercially feasible.

Levelised cost of energy (LCOE) can be regarded as the minimum constant price at which electricity must be sold in order to break even over the lifetime of the project. The following table shows the LCOE of various energy sources:

Wind Energy (onshore)	$29 per MW h
Solar Energy	$50 per MW h
Biomass Energy	$50- $150 per MW h
Hydro Energy	$122 per MW h
Tidal Energy	$197 per MW h
Coal (conventional)	$102 per MW h

Table 3:Production cost (LCOE)

In future the cost of fossil fuel is expected to go up and that in turn will increase the LCOE of conventional energy, furthermore the recent advancements in the generation and storage technology of renewable energy is only going to reduce the LCOE of renewable energy. In addition the many government provide subsidies for renewable energy that further reduces the LCOE of renewable energy.

Installation cost is the one time investment required to set up the power plant. This cost depends upon the size of the power plant and the type of power plant. To give a comparison between various types of power plant based on energy source, cost per MW is calculated and presented in table 4.

Wind Energy (onshore)	$2.2 million per MW
Wind Energy (offshore)	$2.5 million per MW
Solar Energy	$1 million per MW
Biomass Energy	$820K-$7.6 million per MW
Hydro Energy	$1- $5 million per MW
Tidal Energy	$5.1 million per MW
Coal Energy	$3.5 million per MW

Table 4: Installation cost

Biomass energy has a very wide range of installation cost and that is because there are many technologies in biomass energy, based on the type selected the installation cost varies. Figure 3 lists the different types of biomass energy and their installation cost.

	Equipment type	Feedstock type and cost (2010 USD/tonne)	Total investment costs (2010 USD/kW)
Case 1	Stoker, 50 MW	Forest residues @ 25/tonne	4 264
Case 2	Stoker boiler, 40 MW	Bagasse @ 11/tonne	3 280
Case 3	CFB boiler, 30 MW	Pellets @ 110/tonne	2 116
Case 4	BFB boiler, 40 MW	Energy crop @ 50/tonne	4 400
Case 5	Stoker boiler, 20 MW	Agricultural residue local @ 30/tonne	2 296
Case 6	Gasifier GT, 30 MW	Woodchip local @ 80/tonne	5 256
Case 7	Gasifier ICE, 4MW	Woodchip IC local @ 60/tonne	2 470
Case 8	LFG ICE, 5MW	Biogas @ 0.030/tonne	2 460
Case 9	Digester, CT 8MW	Biogas @ zero	3 540
Case 10	Digester ICE, 1MW	Manure slurry @ zero	5 053
Case 11	Digester ICE, 1MW	Energy crops @ 40/tonne	6 603
Case 12	Stoker CHP, 5 MW	Energy crop @ 40/tonne	4 920
Case 13	Stoker CHP, 25 MW	Agricultural residue local @ 40/tonne	5 104
Case 14	Gasifier CHP 600 kW	Woodchip local @ 70/tonne	7 540
Case 15	Co-firing, separated feed	Woodchip local @ 60/tonne	984
Case 16	Co-firing, mixed injection	Pellets @ 110/tonne	820

Fig 3

Along with the installation cost, the cost of operating and maintaining the power plant is also applicable. The following table gives the operating and maintenance costs (O&M) of different types of power plants:

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Table 24. AEO 2009, O&M Costs

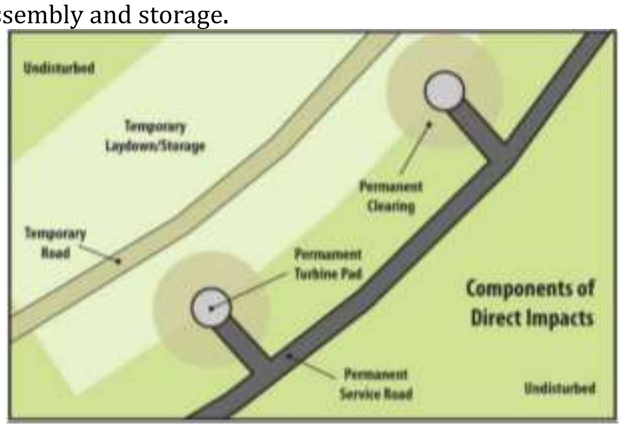
Technology	O&M Variable (2007$/MWh)	O&M Fixed (2007$/kW/yr)
Coal	4.59	27.53
IGCC	2.92	38.67
IGCC w/ CCS	4.44	46.12
Combined Cycle (conv.)	2.07	12.48
Combined Cycle (adv.)	2.00	11.70
Combined Cycle with CCS	2.94	19.90
Combustion Turbine (conv.)	3.57	12.11
Combustion Turbine (adv.)	3.17	10.53
Fuel Cells	47.92	5.65
Nuclear	0.49	90.02
DG (base)	7.12	16.03
DG (peak)	7.12	16.03
Biomass	6.71	64.45
MSW, LFG	0.01	114.25
Geothermal	0	164.64
Hydro	2.43	13.63
Wind (onshore)	0	30.30
Wind (offshore)	0	89.48
Solar Thermal	0	56.78
PV	0	11.68

Power plants require a lot of land to be set up, and different kind of energy sources have different land use requirement. The following table will give a comparison of the amount of land required by different energy sources to produce 1 MW of energy:

Wind Energy	30-44.7 acres per MW
Solar Energy	3.2-6.1 acres per MW
Biomass Energy	3.5 acres per MW
Tidal Energy	42.6 acres per MW

A group of Norwegian scientists did a study to calculate the average land occupation of hydro power plants, according to their research they found out that average hydro power land occupation is between 0.007 to 0.027 m2.yr/kWh.

The calculation for land use requirement for wind energy is very complex and highly variable. Wind turbines require a permanent area and a temporary area for assembly and storage.

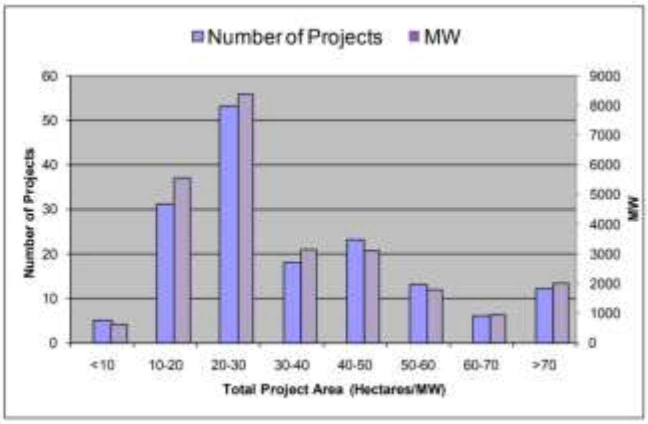


The following is data collected from 161 wind farms in US and then the data is compiled to find the average land use requirement:

Table 1. Summary of Collected Wind Power Plant Area Data

Data Type	Direct Impact Area: Permanent	Direct Impact Area: Temporary	Total Area
Number of Projects with Corresponding Data	93	52	161
Total Capacity (MW) with Corresponding Data	13,897	8,984	25,438
Total Number of Turbines with Corresponding Data	8,711	5,541	15,871
Total Reported Area (km^2)	37.6	61.4	8,778.9
Average Area Requirements (hectare/MW)[4]	0.3± 0.3	0.7 ± 0.6	34.5 ± 22.4

The area required for different size wind power plant is different. The following bar graph illustrates the land use requirement based on the size of the project:



The investment in a power plant is considerably large, so it is important to know the life time of the projects for our investment. The following table gives the life time of different power projects according to different data sheets:

Table 11. Plant Lifetime (years)

Technology	AEO	GPRA	NREL-SEAC	MiniCAM	EPA	MERGE[1]	Standard Deviation	Coefficient of Variation
Coal	X	—	60	45	X	30	15.0	33%
IGCC	X	—	60	45	X	30	15.0	33%
Combustion Turbine	X	—	30	45	X	—	10.6	28%
Combined Cycle	X	—	30	45	X	30	8.7	25%
Nuclear	X	—	60	60	X	30	17.3	35%
Biomass	X	—	45	45	X	30	8.7	22%
Geothermal (hydrothermal)	X	+	20	30	X	—	7.1	28%
Wind (onshore)	X	20	20	30	X	30	5.8	23%
Wind (offshore)	X	20	20	—	—	—	0.0	0%
Solar Thermal	X	30	30	30	X	30	0.0	0%
PV	X	30	30	30	X	30	0.0	0%

— Technology not included in data set
X Technology included in data set, but lifetime not pre-determined
+ Technology included in data set, but lifetime not reported

2.3 CO2 Emission Reduction

Renewable energy technologies could reduce carbon dioxide emission by replacing fossil fuels. Life cycle CO2 emission for renewable energy is much lower compared to fossil fuels.based on an analysis performed by IEA, renewable power generation enabled countries saved 1.7 Gt of CO2 emission in 2008, a figure that is more than the total carbon emission from power sector in European region.

Following is a comparison of the CO2 Emission from different energy sources:

Wind Energy	4 gCO2e/KWh
Solar Energy	6 gCO2e/KWh
Biomass Energy	98 gCO2e/KWh
Hydro Energy	18.5 gCO2e/KWh
Tidal Energy	24 gCO2e/KWh
Coal Energy	109 gCO2e/KWh
Global target for 2050	**15 gCO2e/KWh**

The vegetation which is submerged under the water at dam side to create the reservoir in hydro power projects rots under anaerobic conditions and produces a large amount of methane, which is a green house gas. But this process happens only during the initial period of the plant installation.

Energy Payback time (EPBT) of a power generating system is the time required to generate as much energy as consumed during production and lifetime operation of the system. The hydro power turbine size of 7MW have a potential in electricity production is 38.45 GWh/year. For economic evaluations, energy payback can be met in time period of 12 years and 5 months. The benefit cost ratio on the investment is 1.34 and the yield of the project is 13.28%. Based on Life cycle Analysis (LCA) of offshore wind farms, Schleisner (2000) in his research predicted that the energy payback time would be 0.39 years, or less than 2% of its life span. The SeaGen tidal device was calculated based on LCA to have an energy payback period of 14 months and a CO2 payback period of 8 months. Research has found that energy payback estimates for a rooftop PV systems are: 4 years for systems using current multicrystalline-silicon PV modules, 3 years for current thin film modules, 2 years for anticipated multicrystalline modules, and 1 year for anticipated thin film modules. Based on the LCA of a biomass power plant with a life cycle of 25 years, it would take about 2.5 years for energy payback of the plant.

3. FEASIBILITY STUDY

The purpose of feasibility study is to mold a validated conclusion on expediency of the power and energy construction project implementation for the needs of the enterprise.

Hydro Power Plant

The most important factor in checking the feasibility of hydro power plant is the amount of water that the dam might collect throughout the year. Also it is important to find out the maximum and minimum water level throughout the year. Secondly it is important to find the head of water. In order to generate a requisite quantity of power, it is necessary that a large a large quantity of water at sufficient head should be available. For a commercially viable site it would normally need to be at least 25 kW maximum power output. For a low head micro power plant system one would need at least 2 meters of gross head and an average flow rate of 2.07 meter cube per sec. The site selected should have proper rail and road transportation facilities. The land to be selected should be cheap and rocky. The rock should be impervious and stable at all conditions.

Wind Power Plant

For feasibility of a wind farm it is important to select a site that has a minimum wind speed of 12-14 km/h throughout the year. For the turbines to work at full capacity the wind speed should be between 50-60 km/h. If the wind speed increases more than 90 km/h then the turbine stops working. Other than wind speed a variety of other factors must be considered like roads, woodlands and hedges, buildings, power lines, water courses, other landscape features that will impact the turbine location. Other than this one also needs to consider the aviation, communication, ecological and cultural heritage before selecting a location for a wind farm.

Tidal Power Plant

A tidal range of at least 7 meter is required for economical operation and for sufficient head of water for the turbines. Tidal energy schemes are characterized by low capacity factors, usually in the range of 20-35%. The waters off the pacific northwest are ideal for tapping into an ocean of power using newly developed undersea turbines. The tides in the northwest coast fluctuate as much as 12 feet a day. On Atlantic seaboard, Maine is also an excellent candidate. Sea is a hostile atmosphere hence the machinery used should be robust in nature. the "Gibrat" ratio is the ratio of the length of the barrage in meters to the annual energy production in kilowatt hours. The smaller the Gibrat ratio, the more desirable the site. The Gibrat ratio of La Rance, one of the biggest tidal power plant in the world (240 MW), is 0.36.

Solar Power Plant

The location where a solar power plant will be installed is highly related with the solar energy potential of the location, sunshine duration in hours and PV type area energy generation. Another main criterion is surface slope. The slope of the surface where the solar power plant needs to installed should be less than 5% slope coefficient. Other than this it is important to see the infra structure of the location for transport of machinery and parts. Cost of land should be cheap as these plants require a large amount of land. The site selected should have many clear days with minimum cloudy or rainy days.

Biomass Power Plant

The availability of biomass, use of land, roads and electrical supply network are the major factors considered before selecting a site for biomass power plant. Furthermore it is important to study the type and quantity of biomass available before selecting the type of biomass power plant.

3. CONCLUSIONS

Wind energy has the cheapest LCOE, with an average installation cost, and high land use requirement. Solar energy has a cheap LCOE and cheap installation cost, but its very unpredictable and has the lowest efficiency. Tidal energy is very predictable and reliable, but it only gives output for around 10hrs a day. The technology used for harnessing tidal energy is well developed but the cost of construction is high, with possibly a 10 year construction period. Biomass has a lot of different types of technology and based on that the installation cost and LCOE varies a lot, but for most types of biomass energy production the carbon emission is very high, hence it beats the purpose of tackling climate change. Hydro energy has a variable installation cost based on the quality of location selected, but the LCOE of hydro power is higher than conventional energy sources. Moreover the reservoir created behind the dam is bad for ecosystem of the area and might displace any settlements in the area. Now a days a hybrid of these technologies are most preferred. Based on the geological condition of the place the most suitable form of energy must be chosen to work along with some other form of energy because most of the energy source is not reliable to supply the grid continuously alone.

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