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Statistical Analysis of The Potential of Renewable Energy in Running Vehicles for Rajshahi City

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Abstract

Increasing environmental concerns and the depletion of fossil fuel resources have accelerated the exploration and utilization of renewable energy sources in transportation. This paper shows a statistical analysis of the potential of renewable energy to run vehicles in Rajshahi. Analysis shows, if a wind turbine of 0.88 m blade length installed on a car and runs at a speed of 60 km/h (6 h/day), can achieve approximately 69.78% more milage compared to a car without wind turbine. Besides, if a solar panel is installed on the same car, it can produce 2.926 kWh/day power on average and 12.9367 km could run by the solar power, for maximum power it would be 16.7921km. For Biomass energy, it can run 71.465km by the power produced from 1 kg of methene. Based on analysis, renewable energy sources can play a vital role to reduced dependency on fossil fuel in case of vehicle.

Keywords: Solar Energy, Biomass Energy, Wind Energy.

1. Introduction

Global attention is being drawn to more manageable solutions for energy sustainability as a result of environmental degradation, the depletion of fossil fuel reserves, and rising greenhouse gas emissions. One of the most promising approaches to this goal is to integrate renewable energy sources into our transportation infrastructure. Transport continues to be one of the largest contributors to global greenhouse gas emissions, responsible for nearly 12% of direct CO_2 emissions from fuel combustion [1]. So, reducing the usage of carbon fuels in transportation systems lowers greenhouse gas emissions and lessens reliance on non-renewable fuels like petrol and diesel and increase dependency on vehicles powered by renewable energy such as solar, wind and biofuel etc.

The primary incorporation of solar energy is done in the transport sector by installing photovoltaic (PV) modules on the external surfaces of electric vehicles (EVs) and EV infrastructure. Solar EVs, which are quite experimental as of now, are capable of charging themselves by transforming sunlight into electricity even whilst running. As an example, Yap et al. (2022) have investigated the integration of solar panels on the roof of electric cars to boost the battery charging while driving due to the faster charging capacity of solar energy [2].

In addition, materials selection of photovoltaic solar panel has been one of the prevalent solutions to replenishing electric vehicles especially in areas with low sun exposure. Kim et al. (2021) used polymer material in a sandwich structure, to obtain nine times stiffer rigidity compared to an aluminum sheet of the same weight, less weight, and collection of solar energy at different times to make sure the maximum amount of solar energy is collected [3]. In addition to presenting statistics demonstrating that the integration of wind energy into transportation can reduce fossil fuel use by 20–30%, Md. Faruque Hossain's research demonstrated that a vehicle can be fully charged in two hours if it runs at 10 kph. It only takes 20 minutes for a car to get fully charged while running at 60 kph [4].

In general, it is observed that biofuels reduce petroleum consumption in the transport sector by 20-30%, particularly those produced from second-generation feedstock, agricultural residues, and non-edible crops. One case study by Karp et al. relates to a country like Brazil, where ethanol, being a biofuel extracted from sugarcane, has become so popular in vehicles that it has reduced the demand for gasoline by about 40% [5].

The scenario of renewable energy in the transportation sector provided above shows that there is a lot of potentiality of renewable energy, which will reduce the sector's reliance on fossil fuels and its negative environmental effects. The possibilities of renewable energy, such as solar, wind, and biofuel, for transportation in Rajshahi City are the main emphasis of this study and data of statistical analysis are presented.

2. Wind Energy for Vehicle Propulsion

One of the energy sources with the fastest global growth is wind energy technologies. The design of a wind turbine is influenced by various elements, such as electrical output control, generator characteristics, rotor-generator matching, and rotor aerodynamics. In particular, rotor aerodynamics is crucial to the harvesting of wind energy. Wind turbine rotor aerodynamics have been extensively studied. Many researches [6, 7] have been done about running vehicles using this wind power that is extracted from the wind turbine.

This study emphasizes on the potential of wind turbine energy for vehicles in Rajshahi city. Transportation of this city wholly depends on vehicles called auto that is powered by electric energy. Therefore, this source's load in this city has a significant impact on the national grid. Finding other renewable energy for transportation becomes obvious for meeting electric demand on others sector. Here, wind energy may be quite significant. In Rajshahi, the wind speed at its maximum, minimum, and average values are 3.73, 1.45, and 2.46 m/ respectively [8].

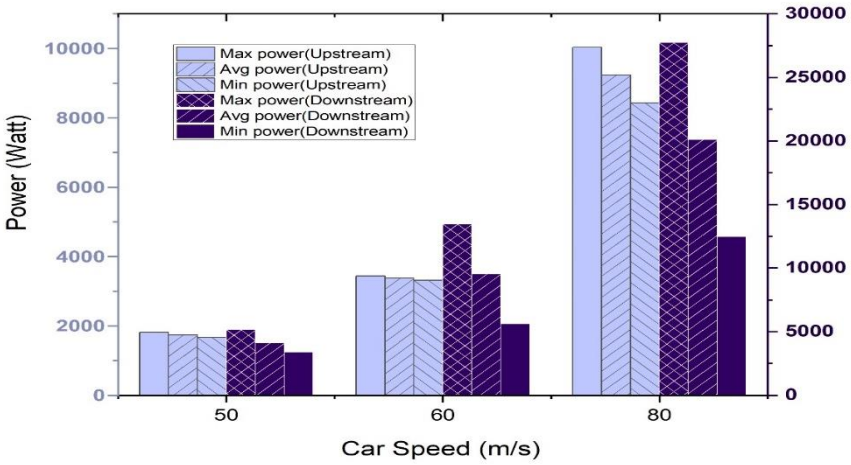


Fig. 1. Power generation at vehicle speed of 50,60 and 80 km/hr for upstream, downstream and average condition

Fig.1 shows the power of wind turbine with respect to vehicles velocity. 50, 60,80 km/hr vehicles speed were taken for this study as these are the major traffic speed for Bangladesh [9]. For both upstream and downstream generated electric power were calculated using equation 1, considering dry air has a density of 1.293 kgm^{-3} at a temperature of 273 K and a pressure of 101.325 kPa [10].

$$P = 0.5 \times C_p \times \rho \times \pi \times R^2 \times V^3 \quad (1)$$

Cp = 59.3%

At 80 km/h, a vehicle can obtain a maximum power of 10034.529 W during upstream travel, supporting 58% of the total distance travelled and a minimum of 15.395%. For downstream, it is possible to completely run-on wind turbine. On average 69.78% of the total distance traveled may be covered by wind energy.

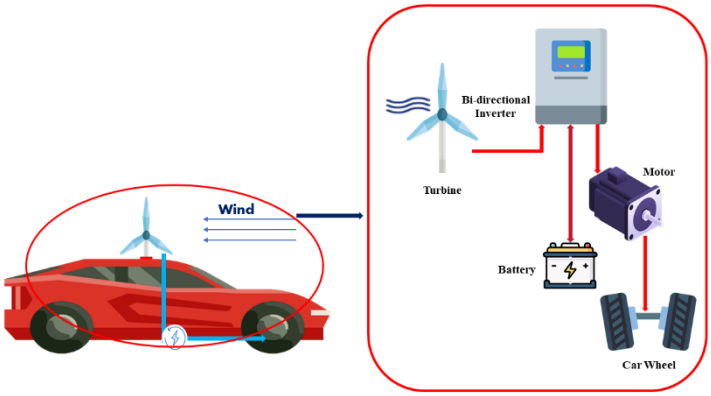


Fig.2. Schematic diagram of running vehicle using wind turbine

Fig.2 depicts a schematic diagram of a wind turbine placed above a vehicle. The wind turbine's power is utilized to run a motor, which drives the wheels of moving vehicles. In order to store excess energy to support vehicles in the absence of wind, a bidirectional inverter system is used with batteries.

3. Solar Energy for Vehicle Propulsion

Solar energy has the potential to revolutionize the transportation sector, with its endless and sustainable power source. Its use in solar-powered transportation systems and electric cars might significantly lower carbon emissions in addition to providing a practical means of enhancing environmental sustainability. Additionally, future advancements in photovoltaic technologies and solar infrastructure hold promise for lowering transportation energy use and improving economy. The use of solar energy is growing, and this has an impact on how the foundation of cleaner and more environmentally friendly transportation solutions is formed globally.

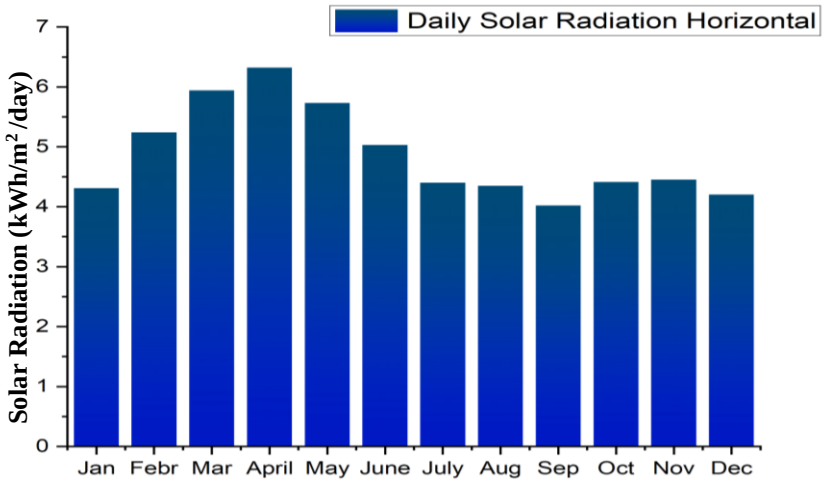


Fig.3. Daily solar radiation of twelve months in 2022 [11]

Fig.3 shows the daily solar radiation of twelve months in 2022 which was traced in Rajshahi of Bangladesh. The solar radiation varies from month to month. In Rajshahi Solar intensity remains maximum in April and minimum in September. In April 2022, Solar intensity was 6.33 kWh/m^2/day and in September which was 4.03 kWh/m^2/day. On average the daily solar radiation of the Rajshahi was 4.8767 kWh/m^2/day which is a significant amount of solar radiation that may be used to generate electricity.

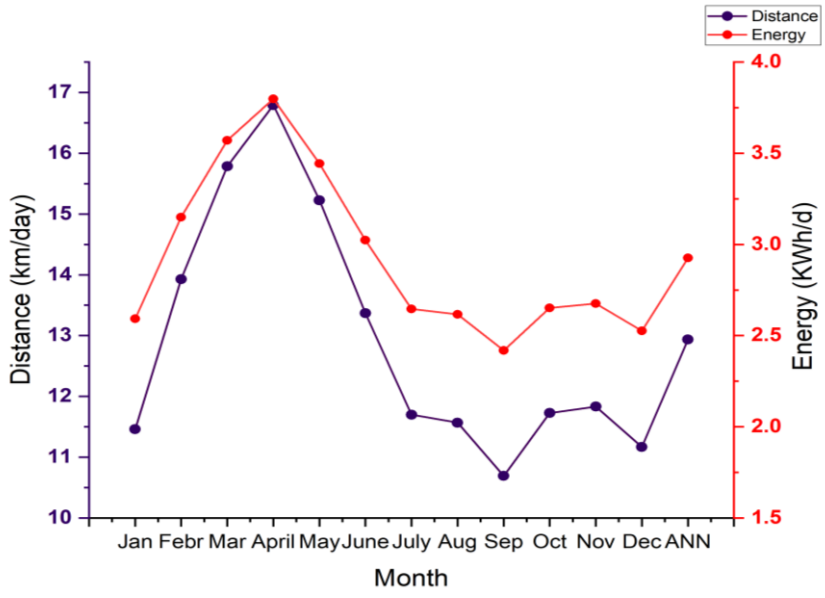


Fig.4. Monthly average energy absorbed on a horizontal surface (ANN- Annual average)

On average, electric cars consume 34.6 kWh power to travel 100 miles. That means 0.346 kWh per mile [12]. However, in 2022 the maximum power was recorded at Rajshahi in April which was 3.798 kWh/day and the minimum power was recorded in September which was 2.418 kWh/day showed in Fig.4. On average 2.926 kWh/day power was recorded at Rajshahi in 2022 which is significant amount of energy in the perspective of Rajshahi as well as Bangladesh. By using this vast amount of energy, a car will able to travel at least 8.0385 miles

per day. So, solar energy can be an alternative of fossil fuel for running vehicles. To calculate solar energy (2) is used:

$$E = A \times H \times \eta_{Con} \quad (2)$$

Where E is the total energy output in kWh/ day, A is the square area of solar PV system in square meter (m^2), H is the solar radiation in (kWh/ m^2/ day) and η_{Con} is the conversion efficiency (%). Standard solar energy conversion efficiency Range is (14-20%) [5]. Here, energy conversion efficiency was taken 20% as the standard solar energy conversion efficiency. Standard area of solar PV system A=3 m^2 [13].

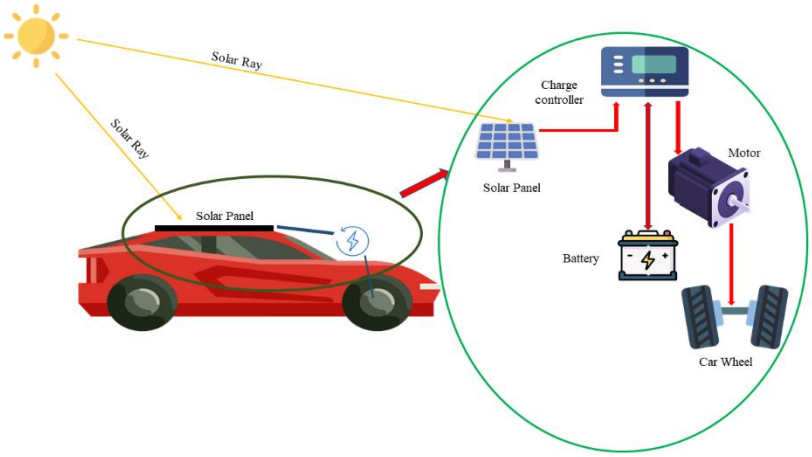


Fig.5. Schematic diagram of running vehicle using solar power

Fig.5 depicts a schematic diagram of a solar panel placed above a vehicle. A charge controller is used to control overcharging, discharging and prevent back flow of electricity from battery at night. Electric motor is installed to power the wheel of car. This figure displays the solar energy to final wheel power flow model.

4. Biomass Energy for Vehicle Propulsion

When it comes to being the most advanced and widely utilized renewable energy source for transportation, biofuels rank highly. Biofuels, such as bioethanol and biodiesel, are made from waste oil, animal fats, plant biomass, and other materials. These fuels are especially well-suited to the aviation and heavy-duty transportation markets because they can be co-blended, or utilized interchangeably, with traditional fossil fuels in internal combustion engines that are currently on the market. Biomass fuels can be an alternative for that in running and other systems. The amount of greenhouse gas emission of biomass fuels is also less than that of fossil fuels. In this paper, energy content in biomass and approximate distance that can be traveled per kg of each biofuel are explained.

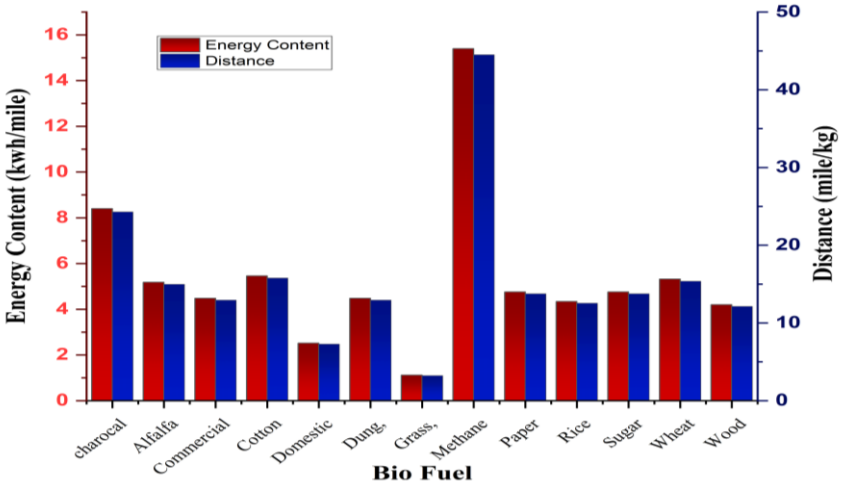


Fig.6. Energy content in biomass [14]

Energy content in MJ for per kg of different biomasses are shown in Fig. 6. And how much power can be produced from these biomasses are also demonstrates here. In average a car needs 0.346kWh/mile (1.6km) [12]. So, for 1kg of charcoal the car can travel (8.4/0.346) 24.28 miles.

In Bangladesh region domestic refuse, dung dried, methane from biogas, rice hulls, sugar cane residues etc. are common biomasses [15]. Among them maximum energy found from methane biogas and it is 15.4kWh and by using this biofuel the maximum distance can be travelled in a day is 44.5 miles.

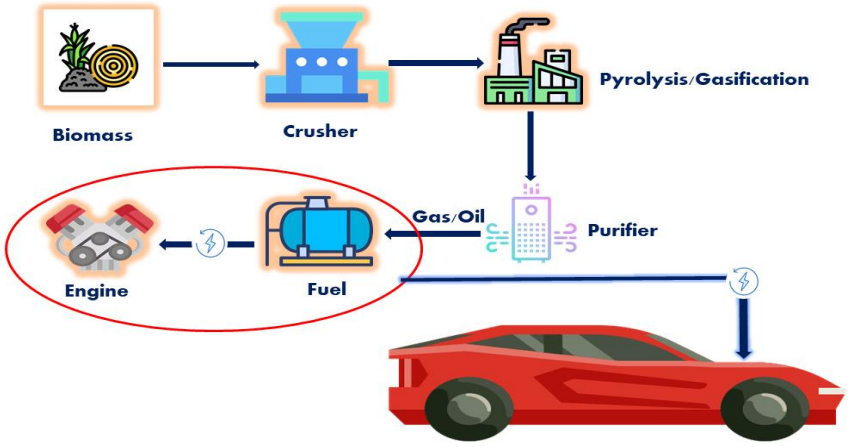


Fig.7. Schematic diagram of biomass used as a fuel in vehicle.

Fig.7 illustrates a schematic representation of a biomass system. This system necessitates a pyrolysis plant to produce bio-fuel from biomass, which is then utilized to power vehicles.

5. Recommendation and Challenges

The above statistical analysis depicts that biomass energy has huge potential as compared to solar and wind energy. Biomass has higher performance of approximately 50 miles per Kg of methane while the solar energy can facilitate only 17 kilometers distance per day. Wind energy facilitates approximately 69.78% additional distance. In infrastructural facilities, biomass energy production for generating biofuel is much more expensive than other options. The wind turbines require an advanced and expensive system, it needs to conduct extensive research on available vehicles so that wind turbines can be fitted in already-running vehicles. Stability, cost, and efficiency are the major issues, especially for Rajshahi city. Therefore, taking everything into account, solar energy may be a smart way to save energy in the transportation sector of Rajshahi, provided that all that is needed is the installation of an affordable, basic solar panel and control system.

6. Conclusion

The evaluation of renewable energy opportunities for transport in Rajshahi city explores favorable prospects. Wind energy as used through a turbine has the potential to get a car fully charged traveling at a speed of 80 km/h with a downstream wind velocity of 3 m/s. At 60 km/h car speed, about 69.78 km more distance can be covered by wind energy after 100 km of driving. Solar Energy, allowing the car to cover a mean of 12 km a day, the maximum being 16.5 km/day in certain months, such as April. Of all the sources, methane biogas is the most efficient, with an output of 15.4 kWh to give a maximum of 44.5 miles per day. Based on the preceding analysis, it can be said that renewable energy sources like solar, wind, and biomass can play a vital role in reducing dependency on fossil fuels in passenger vehicles, which can be beneficial for both the economic and environmental conditions of Rajshahi.

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