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Energy Sources for Charging Electric Vehicles in Pakistan: A Solution to Global Problem

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Abstract: The fossil fuel reserves, which provide energy for conventional automobiles, are almost at their limits. Additionally, these automobiles' exhaust fumes harm the environment by releasing more greenhouse gases into the atmosphere. Electric vehicles (EVs) are a brand-new form of transportation that are being developed to address these problems. Dependable charging infrastructure is also becoming more important as demand for electric cars rises to support the quick uptake of this mode of transportation by the general population. Local electricity grids are simultaneously under stress and need assistance from cheap, plentiful, and renewable alternative energy sources. This is the reason why highly praised renewable energy-based charging stations have lately appeared across countries. In this paper, we examine several forms of alternative energy sources, with a focus on charging infrastructure & reduction in emissions for electric vehicles in Pakistan. In terms of economics and environmental friendliness, the study offers thorough calculations of internal combustion engine emissions as well as an assessment of several renewable and non-renewable energy sources for electrical vehicle charging.

Keywords: Energy, Greenhouse Gases, Electric Vehicles, Alternative Energy, Emissions.

1. Introduction

Global warming is a proven threat to this planet. The major contributor to this threat is greenhouse gases (GHGs) that are released into the atmosphere by different sectors, one of the major sectors is transportation where automobiles require fossil fuels to run and ultimately release tonnes of GHGs each day globally. Massive amounts of pollutants are released from the time that fuel is extracted from wells until it is burned in the tanks of vehicles. According to estimates from 2013, the energy used by the transportation industry accounted for 27.6% of all energy used globally, with oil products providing 92.6 percent of that energy [1]. Additionally, transportation contributed 22.9 percent of the world's total carbon dioxide emissions[2].

Engines fueled by fossil fuels are built by manufacturers for transportation purposes. However, they are in danger of being extinct because of the reckless usage of fossil fuels. Additionally, these cars' byproducts pollute the environment. The main reason for the need for change is the considerable role that these vehicles play in air pollution [3]. Due to their low carbon footprint, electric vehicles (EVs) are growing in popularity. The transport and power system industries will profit greatly from the widespread use of EVs, both economically and environmentally.

To achieve sustainability goals, several countries have enacted long-term mitigation plans in which the replacement of internal combustion engine-based vehicles with electric vehicles is suggested. By the turn of the twenty-first century, a conspicuous amount of work was being done on electric vehicles (EVS), which are now being highly promoted around the world on the basis of their zero tail emissions [4]. By bringing EVs to their commercial markets, both industrialized and developing nations are making attempts to lessen their reliance on fossil fuels. For certain countries, finding enough electricity to power electric vehicle charging is still a problem since charging electric vehicles with energy from fossil fuels results in higher greenhouse gas emissions than charging them with energy from renewable sources [5]. Since the need for energy is rising at an exponential rate, conventional energy sources won't be around for much longer. Renewable energy sources would be a fantastic option to fulfil future demands and promote sustainable development.

Pakistan's transportation sector is now significantly reliant on hydrocarbon fuels, the majority of which are imported. According to one estimate, the cost of oil imports exceeds 13.3 billion US dollars annually, and under normal economic conditions, that cost is expected to rise to \$30.7 billion by 2025 [4]. When compared to the rate of energy consumption, the contribution of renewable resources in energy generation is growing in Pakistan at a relatively slow rate, and the country's reliance on imported fuel is growing with time, pushing up the cost of imports. An electric vehicle strategy outlining the advantages of deploying EVS in Pakistan and how they would be supported was released by the ministry of industry in 2020. Additionally, the Pakistan government (GOP) developed the first marketing strategy for green and carbon-free technologies. Over a five-year period, about 100k electric cars will be imported from various regions of the world, according to the regulatory authorities' declaration [6]. By 2030, By imposing a 1% general sales tax on imports of different sectors, it is intended to transition about 30% of all cars to electric ones, saving the state at least two billion rupees in fossil fuel costs and lowering CO_2 emissions. However, the issue of charging these automobiles received little attention. The grids would be overloaded with additional energy demand if the number of EVS on Pakistani roads expanded with the aid of subsidy reduction. This study evaluates several energy sources (both

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renewable and non-renewable) in Pakistan and advise which will be the most advantageous from a social, economic, and environmental standpoint when it comes to powering EVS.

2. Materials and Methods

The environment is the main gainer from the transition from conventional to electric automobiles. A significant obstacle is the lack of infrastructure for charging these automobiles. The main prerequisite for charging vehicles in large numbers is technological development in EV battery charging. To come up with better solutions, the sources for charging EV batteries must be thoroughly investigated. The availability and effectiveness of the charging stations determines how widely used and successful EVs will be [7].

2.1 Emission from the Internal Combustion Engines

Recent efforts to reduce ICEVs' (internal combustion engine vehicles') air pollutant emissions are crucial for focusing attention on reducing road transport's carbon dioxide emissions. Based on several sets of variables that influence fuel consumption and therefore the emission of harmful substances, the article computes the harmful substance emission produced by ICEVs in Pakistan. The automobiles in the mini, small, medium, and large categories were chosen to calculate emissions. Calculation of the emission of each harmful substance from combustion processes is made to determine the emissions from the chosen ICEVs

Table 1. Calculation of Emissions based on average distance

Sr.	**Category**	**Types of vehicles**	**No of vehicles**	**CO_x (kg)**	**NO_x (kg)**	**SO_x (kg)**	**PM (kg)**	**Total Emissions (kg)**
1	Mini	Bikes	10	16.09	0.036	0	0.45	16.576
		Rikshaws	10	67.08	0.89	0.01	1.23	69.21
2	Small	Cars	10	98.07	3.425	1.224	4.444	107.163
		Wagons	10	140.49	24.75	7.8	8.745	181.785
3	Medium	Buses	10	447.99	45.09	14.24	28.19	535.51
4	Large	Trucks	10	188.8	31.23	16.75	9.924	230.78
		Tractors	10	197.4	19.18	13.24	11.11	140.93
Total Emissions				1355.92	124.601	51.264	64.093	1281.954

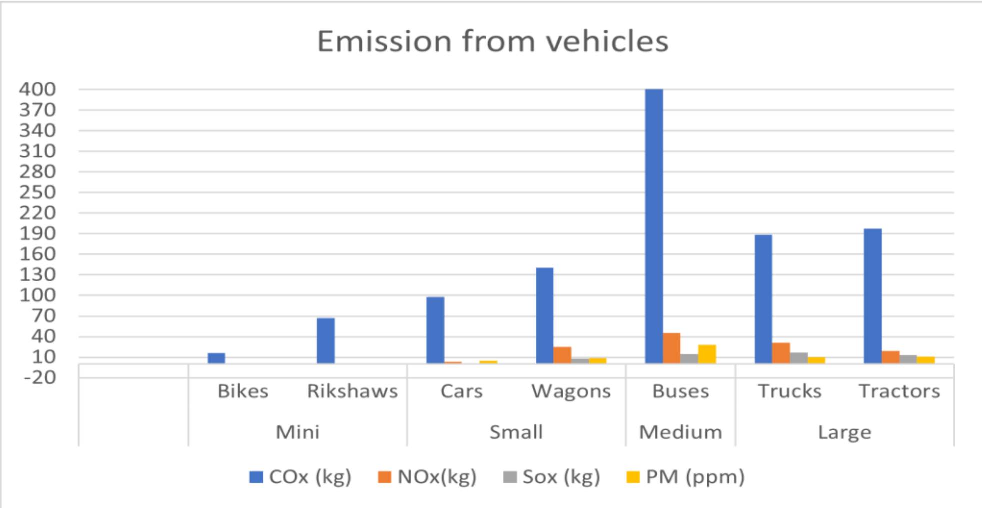

Fig 1. Emission from vehicles

The formula (1) was used to calculate the NO_x, and PM emissions from internal combustion engine vehicles [8,9].

$$E_{i,j} = M_{i,} \times EF_{i,} \text{ ----------------------- } (1)$$

Where, E_i- emission of pollutant i, EF_i – emission factor of pollutant i for vehicle category j and M_i- distance driven by vehicle category j [km].

The emission of CO_2 from vehicles was determined based on formula (2) [8,9].

$$E_{CO2} = EF_{i,j,m} \times FC_{j,m} \text{ -------------------------- } (2)$$

E_{CO2}- emission of pollutant CO_2, $FC_{j,m}$- fuel consumption of vehicle category j using fuel m over the distance driven by the vehicle, $EF_{i,j,m}$- fuel consumption specific emission factor of pollutant CO_2 for vehicle category j and fuel m.

The emission of SO_2 form vehicle with internal combustion engine was determined by the formula (3) [8,9]

$$E_{SO2} = 2 \times k_s \times FC_m \text{ --------------------------- } (3)$$

E_{SO2}- emission of SO_2 per fuel m, k_s- weight related sulphur content in fuel of type m, FC_m- fuel consumption.

The scenario was created by taking into account the typical mileage of the car and the results of questionnaires or performa's filled out at stations by various drivers. It was computed to be emitting 1356 kg of CO_2, 124.6 kg of NO_2 and 51.3 kg of SO_2.

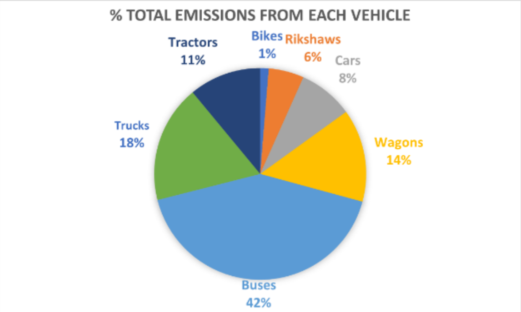

Fig 2. Percent Emission from individual vehicles

2.2 Energy Sources for Charging Electric Vehicles in Pakistan

For electric cars to be sustainable, the electricity needed to charge them must originate from green energy sources that's why a variety of renewable and non-renewable energy sources were evaluated in order to determine which one would be most suitable for use in electric vehicle charging. The cost, emission, power density, efficiency, life expectancy, and accessibility of the distribution network are taken into account while evaluating the source for EVs. There is a thorough description of the many sources that are available for EVCS standalone systems.

2.2.1 Non-Renewable Sources

In Pakistan production of conventional energy relies heavily on non-renewable sources including coal, oil, gas, and nuclear. To produce power, they are employed more frequently than renewable sources [10].

2.2.2 Coal

Pakistan has own coal reserves of total 186 billion tons which is 331.1 times its yearly usage [11]. However, most of the coal consumed in the power industry is imported from other nations because the coal is of lignite quality [12]. Considering this, it will be highly expensive to charge electric vehicles in Pakistan using coal-powered electricity. Though the energy intermittence is reliable, but the coal's quality is so poor that it contains a lot of pollutants like Sulphur, which causes harmful emissions [13] into the environment when used to generate energy, ultimately results in low power density and efficiency.

2.2.3 Natural Gas

As of 2017, Pakistan ranked 29th in the world with 19 trillion cubic feet (Tcf) of known gas reserves [14]. In Pakistan, the most common fuel utilized to generate energy is natural gas. Around 27.7% of the power generated in 2021 came from this source. Natural gas is also used for commercial and residential systems and reserves are depleting day by day [15]. Although they won't run out entirely in a month or a year, but their daily depletion raises doubts about whether they can maintain the pressure needed to produce power. Natural gas produces very few emissions that are harmful to the environment but decreasing pressure due to declining reservoirs may induce intermittent usage, which eventually results in low energy density and efficiency for charging electric vehicles [16]. While the infrastructure for distributing, using, and transporting natural gas is well-developed in Pakistan.

2.2.4 Petroleum

It is anticipated that the share of furnace oil-based energy in the total energy mix would decrease to single digit percentage in the upcoming years due to the planned phase-out of oil-based power generation facilities, which have been the face of Pakistan's power industry for more than three decades [17]. Since Pakistan has negligible domestic oil reserves, its oil imports come from foreign nations, and they account for 15 percent of the nation's total electricity generation. The high cost of imported oil increases the burden on customers in both the business and household sectors [18]. Even though oil produces very few emissions, it is not practical to charge electric vehicles using oil-generated electricity due to its unreliable supply and limited availability. Under the current scenario it is impossible for Pakistan provide such a huge gird power for charging electric vehicles in near future[19,20].

2.2.5 Nuclear

For EVs to be successful in assisting with decarbonization targets, meeting rising power demand, and maintaining low electricity costs, nuclear energy is necessary [21]. There are now six operational nuclear power stations in Pakistan, and one more are being built. As of 2018, Around 7.5% of the nation's total energy production comes from commercial nuclear power facilities [22]. The most practical alternative for a consistent supply of dependable, carbon-free electricity for charging electric vehicles right now is nuclear energy [23], but Pakistan doesn't have the potential or reserves to enable this. Its supply is in doubt and installing nuclear-powered charging stations throughout Pakistan's cities poses a risk to people's health and safety.

2.2.6 Renewable sources

A developing country's ability to sustain and lower the cost of its energy supply is strongly correlated with its level of economic activity. Load shedding is a symptom of Pakistan's energy crisis, which results in a daily shortfall of about 6,500 megawatts of electricity. Even though renewable energy accounts for less than one percent of the energy mix today, Pakistan has a solar potential of 2,900,000 MW, a wind potential of 346,000 MW, a biogas potential of 3,000 MW, 2,000 MW of minor hydropower, and 1,000 MW of waste-to-energy. It is recommended that energy planning be optimised, partnerships with commercial sectors and international organizations be strengthened, and management of current resources be prioritized. Renewable energy should be prioritized by local policymakers and planners in order to raise its proportion of total energy and boost Pakistan's sustainable energy profile [16]. The renewable energy sources are plentiful, all-pervasive, renewed naturally, and environmentally beneficial. The most prominent RES in Pakistan is solar and wind energy, which are also used at the business level. Therefore, RES should take the place of traditional energy sources to slow the deterioration of the environment. Not only would switching to RES cut emissions, but it may also significantly boost Pakistan's economy [24].

2.2.7 Solar Energy

The most accessible renewable energy source in terms of quantity is solar energy [25], which is also the least expensive option for charging an electric vehicle compared to other sources [26]. The solar panel's type and material have an impact on its power density and efficiency. A PV solar panel should have a life expectancy of over 25 years [27]. Additionally, as this is the cleanest form of energy, there is no risk of hazardous emissions or environmental contamination. Despite the fact that solar energy may have a low density for a few days in various weather conditions, this shortcoming is tolerable given the other benefits it offers [28]. Solar and wind power have enormous potential in Pakistan. According to the World Bank, solar photovoltaic (PV) power generation on just 0.071 percent of Pakistan's land area could meet the country's current energy needs. For electric cars to be sustainable, the electricity needed to charge them must originate from renewable energy sources rather than fossil fuel-based power plants [29]

2.2.8 Wind Energy

Wind energy is cleanest, cheapest and most abundant source of renewable energy with zero CO_2 emissions [30]. Although there may occasionally be low wind pressure due to seasonal change, this source is still satisfactory to use. There may also be some minor intermittent issues, but those are negotiable. The effectiveness of wind energy depends on the air pressure and the region chosen to install the wind turbines [31]. An average wind turbine will last 20 years, and it will need to be serviced every six months. Variability in power output from wind turbines is a result of the wind's speed, however this variability may be mitigated by using a battery or other energy storage device [32]. The next major energy source for EV charging stations after solar energy is wind. Parking lots can be used as the nacelle for wind turbines with small to medium-sized blades. This type of positioning considerably lowers the cost. The design of the turbine and blades has a significant impact on the system's efficiency [33]. In Pakistan, more than 6% of the nation's total electricity is produced by wind energy, a kind of renewable energy. Pakistan had 1,287 MW of wind power capacity as of 2018. In addition, Pakistan had 26 operating wind power projects with a combined 1335 MW capacity linked to the national grid as of 2022, while an additional ten wind power projects with a combined 510 MW capacity are now under development [34].

2.2.9 Hydropower

Although hydropower is a sustainable energy source, installing hydroelectric stations requires building dams, which makes its harvesting expensive rather installing on already build dams is economical [35]. hydropower has a median greenhouse gas (GHG) emission intensity of 24 gCO_2-eq/kWh - this is the grams of carbon dioxide equivalent per kilowatt-hour of electricity generated allocated over its life cycle [36]. Hydroelectric powerplants are the most efficient means of producing electric energy and unlike other renewable energy sources, such as wind and solar, hydropower is not intermittent [37]. In addition to being one of the most economical energy sources, hydropower is also immune to market fluctuations and embargoes, supporting our country's energy independence now and for years to come. A hydroelectric facility has a 100-year lifetime on average [38].

2.2.10 Biomass

Biomass is a sustainable, environmentally friendly fuel. The sun provides the initial energy, and plant or algal biomass can renew rapidly. Sustainably utilising trees, crops, and municipal solid waste is possible and easy [39]. Although biomass is a versatile source of renewable energy, it is not completely clean, is expensive in comparison to other options, and ultimately contributes to deforestation. Dedicated biomass facilities for combined heat and power (CHP) are generally smaller in size and have poorer electrical efficiency when compared to coal plants (30%–34% for dry biomass and roughly 22% for municipal solid waste). This is due to concerns with feedstock supply. The overall efficiency in cogeneration mode may range from 85% to 90% [40]. Although renewable energy sources such as solar and wind are reliable, they are not constant since the sun doesn't always shine and the wind doesn't constantly blow. Solar and wind power can't always meet your energy needs without reliable storage options. Unlike the availability of some biomass resources, which may fluctuate with the seasons, biomass energy plants may provide electricity year-round, regardless of the weather. There are restrictions on where you can put a biomass energy plant because of the large amounts of water and land they need to thrive. However, there are a number of environmental drawbacks associated with converting biomass into power, and this process can shorten the 20-30 year lifetime of bioenergy [41, 42].

The spider diagram below shows the score for every source taking into account each factor in order to provide a better understanding of the aforementioned evaluation. Each source's factor was given a score of 1 if it is suitable for use in EV charging; otherwise, it is given a score of 0 and the overall viability of an energy source for the use of EVs is determined by the total score based on above literature. Considering the scenario, the solar energy was proven to be the most suitable source to be utilized for charging the EVs.

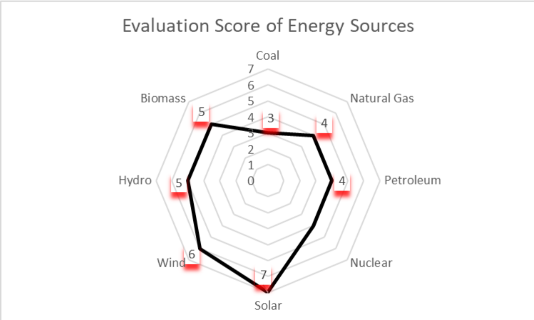

Fig: 3. Evaluation of Renewable and Non-Renewable Energy Sources

3. Conclusion

The net emissions from the vehicles of different category were calculated, the total emissions for average 10 bikes, rikshaws, bikes, wagons, buses, trucks, tractors, are 16.57, 69.21, 107.16, 181.78, 535.51, 230.78, 140.93 respectively. These vehicles use fossil fuel, which already includes the pollutant that the vehicles produce, therefore it stands to reason that the emission from EVs will be lower than that of these vehicles.

Electric vehicles are a new mode of transportation that emits less pollution. The charging of the fleet of EVs will provide a dilemma for society as they proliferate on the roadways. The conventional method used nowadays is charging from the grid supply. It is also thought that the PV-grid architecture works well for charging batteries. However, both topologies will inevitably put the grid network under load stress; what is required is a charging station that is not dependent on utility supplies.

Pakistan's ecology is severely polluted because of rapid population growth, so the government should encourage the use of electrical vehicles. There are several high-density areas where electrical car charging stations might be installed, including parking lots, hospitals, and retail centers. By installing renewable energy technology in the transportation sector, Pakistan may simply address its enormous investment in fossil fuel imports. According to the Government of Pakistan's 2018 Economic Survey, Pakistan uses 33 percent liquid fuel to produce power and 57 percent liquid fuel for the transportation industry. Like how RLNG uses 53 million cubic feet per day and CNG uses over 138 million, the transportation industry uses natural gas. In order to decrease direct investment for importing liquid fuel as well as gas fuel, the government of Pakistan should adopt a policy to create a charging station using RES.

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