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A Review on "Wind energy fuel as a Power Source for Automobiles"

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Abstract

Requirement of energy for automobiles is increasing everyday as we take a step towards development. The use of non-renewable energy sources such as fossil fuels is leading to an increase in pollution. There was research performed by the United States Environmental Protection Agency (EPA) in 2007 and it was found that a normal family car produces approximately three to four tonnes of carbon dioxide per year, similarly six tonnes of carbon dioxide was produced by a large four-wheel drive like a van yearly. The present energy scenario of energy generation and the pollution caused by automobiles due to conventional energy sources have made it necessary to harness energy from other unorthodox sources to run them. Electric vehicles have been developed to solve this problem, in a sense that they don't release any harmful gases such as carbon dioxide and carbon monoxide. One major problem which still exists even in electric automobiles is that the electricity that they utilize is still generated from conventional sources. Thus, if we can somehow generate electricity from unconventional sources, it can solve our former problem. Wind energy fuel which can be harnessed from a moving vehicle is one of such unorthodox sources that could be harnessed and subsequently used to power automobiles. This paper is a review of different ways of how wind power can be harnessed to fully power an automobile.

Keywords: *Doubly-Fed Induction Motor (DFIG), Fuzzy Logic Controller (FLC), Fuel, Horizontal-axis Wind Turbine (HAWT), Medium Scaled Wind Turbine (MSWT), Permanent Magnet Synchronous Generator (PMSG), Vertical-axis Wind Turbine (VAWT)*

1.0 Introduction

The use of alternative energies to power an automobile is popular and required nowadays. Different forms of energy sources like sun, lithium-ion batteries, etc. are used to power a car or any other automobile. Slowly, electric vehicles are replacing conventional petroleum vehicles. This is also a necessary step as engines runned by petrol or diesel cause high pollution. Thus, other sustainable and environmental friendly sources of energy should be used to run an automobile. Companies like Tesla, General Motors, and Nissan are successful and profitable in making all electric cars. Electric cars are good in a way that they don't cause pollution, which are caused normally in petroleum cars. Main problem with electric vehicles is that they don't have as high as petroleum cars, and in developing countries like India, China where almost 70-75% electricity is produced by conventional sources like burning coals, natural gas, etc. Although electric cars will not cause any pollution, electricity generation in the country will cause more pollution. Hence, electric vehicles ultimately still cause pollution, have shorter range and take a lot of time to recharge. Thus, there is a need to produce energy or electricity from unconventional sources which are environmental friendly.

One such energy source is wind energy fuel, it is free, sustainable, inexhaustible and abundantly available in a running vehicle. Earlier wind powered cars were

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made with huge propellers, which was practically and commercially not viable. If we can power electric vehicles by unconventional sources of energy, it can solve our problems with pollution, and can be commercially viable. We can generate electricity by wind which passes by the moving automobile, i.e., by capturing air currents and utilizing it as power. There are basically two types of air resistances acting on moving vehicles, they are:

1. Frictional drag which is caused by viscosity of the air,

2. Form drag caused by difference in the air pressure of the forepart and the rear part of the vehicle.

This method of charging the automobile with the help of wind can significantly increase the range of the vehicle and also help in decreasing pollution. Wind turbines can be placed in many different places thus providing different ways of generating electricity.

There are certain problems which still exist if we use wind as our energy source. The wind turbine which we use to convert wind energy to mechanical energy is normally only 30%-40% efficient, is expensive, and increases air resistance, thus limiting the speed of the automobile. The purpose of this study was to find ways to solve these shortcomings so that wind energy fuel can be successfully harnessed, be economical, and can be practically used in day to day life.

2.0 Literature Review

There are two types of wind turbines that are used in to produce electricity, they are:

1. Horizontal-Axis Wind Turbine
2. Vertical-Axis Wind Turbine.

2.1 Horizontal Axis Wind Turbine (HAWT)

HAWTs are the type of turbines in which the axis of rotation of the rotor is aligned with the bottom and also with the wind directions. HAWTs are generally used in automobiles to generate power in the research papers reviewed.

They are divided into 2 types:

a. Upwind Turbine
b. Downwind Turbine

a) Upwind Turbine: The turbine in which the wind first faced by the rotor is named as an upwind turbine. Upwind types of HAWT are most commonly manufactured turbines today. This type of turbines is mostly used to generate electricity in vehicles in reviewed research papers (Figure 1).

b) Downwind Turbine: The turbines in which the propeller is present at the bottom of the tower are named downwind turbines. In these sorts of wind turbines, the wind first hits the tower and then after that it hits the propeller blades. This type of wind turbine receives some variations in wind power as the rotor passes through the wind shade of the tower. These sorts of wind turbines are not normally used in automobiles to generate power.

2.2 Vertical-Axis Wind Turbine (VAWT)

Vertical axis wind turbine is a turbine in which the

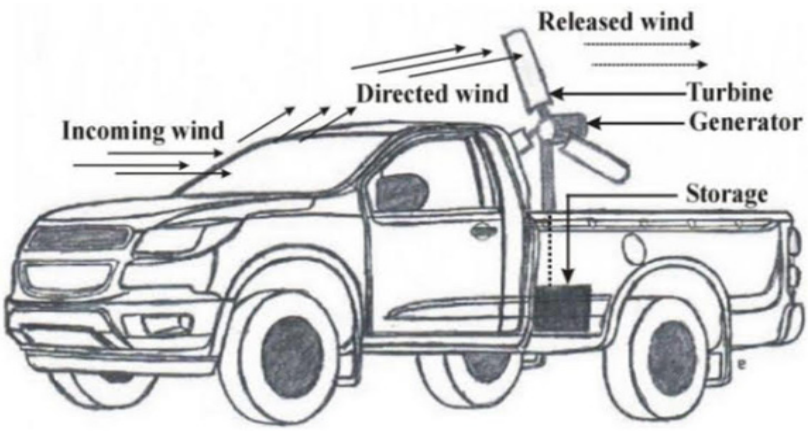


Figure 1. HAWT (upwind) structure of vehicle wind turbine system[1].

rotation axis of the rotor is at right angles with the ground and also with the wind direction. It can also operate in low wind situations. These sorts of wind turbines are relatively easier to construct and carry from one place to another, are mounted near the ground and have the ability to handle the turbulence in a better way compared to HAWTs. This type of wind turbine causes less wind resistance which can be useful for moving vehicles. but because of its less efficiency these are generally not preferred for power generation in automobiles.

VAWTs are classified further as:

c. Giromill turbine
d. Darrieus turbine
e. Savonius turbine

a) Giromill Turbine: One salient feature of the Girmoll turbine is that it has an H-shaped propeller. It works on the very principle as the Darrieus turbine. Although the Giromill turbine is affordable and relatively simple to build if we compare it with the Darrieus turbine, it requires strong wind to start.

b) Darrieus Turbine: This type of VAWT was first formed and patented by French aeronautical engineer Georges Jean Marie Darrieus in 1931. This type of turbine is spinned by using a small powered motor, are used in small off-grid sites, such as a small house, but are not generally used in automobiles.

c) Savonius Turbine: One of the simplest type of turbine is the Savonius turbine. It was first discovered by a Finnish Engineer Sigurd Johannes Savonius in 1922. This type of turbines is found to be more efficient than other VAWT, hence it is also considered to produce power for automobiles.

The following (Table 1) gives a comparison of the instrumentation and parametric features along with the

Table 1. Review on Research Papers on various types of automobiles using wind energy fuel

Authors	Materials Used	Description	Results
Sampath and Suranjan (2019)[15]	Turbine blade made of PVC pipes, 12V DC generator, Aluminium chassis, Mild steel frame, Galvanized iron sheets for the body.	Electric car consists of 6 lead-acid batteries of 8V connected in series. Batteries were connected to the controller which is connected to a 48V, 2.3kW DC motor connected to the rear axle of the wheels. A reservoir battery of the same specification is connected to the vehicle's battery. Reservoir acts as a backup and boosts the vehicle thus maintaining top speed. It can also get charged by the turbine.	Ideal case: Ideally a vehicle running at 35kmph generates 75A with 1500 rpm, thus, recharging the batteries within 3-4hrs. Actual case: a vehicle running at 35 kmph produces power of 315W, thus charging the batteries within 63.5hrs, with a limitation being that the maximum speed of the vehicle will be 35kmph. The actual result is not practical in the real world.
Prajapati and Thakkar (2013)[20]	Regular plastic propeller, dia (310mm), Copper wire, Lamp (1.8V-3V), Dynamometer, Wooden frame.	The experiment is not done on an actual automobile. It is done on small wind turbines at different wind velocities. First the calculated the power in wind by 0.5*air density*area of fan*velocity of wind. Then found the actual power produced by the whole setup, thus, also calculating the efficiency of wind energy fuel converter.	case 1: wind velocity=25km/hr, power in wind=15.16W, power developed= 0.6W, efficiency=3.95, case 2: wind velocity=35km/hr, power in wind=41.56W, power developed=2.4W, efficiency=5.77, case 3: wind velocity=40km/hr, power in wind=62.09W, power developed=3.6W, efficiency=5.79. wind velocity and efficiency are directly proportional.

Herman *et al.,* (2004)[5]	Vehicle alternator, Rectifier bridges, Voltage regulators, Bearings, Battery.	In the experimental set-up, the car alternator is mechanically linked to the shaft of the squirrel cage induction motor, which is then runned through an AC drive. The AV drive imitates the fluctuating speed of the wind. The irregular- frequency voltage generated by the alternator is corrected by an AC/DC uncontrolled converter. This voltage is maintained by the excitation voltage control of the electric generator.	The electric generator provides a useful output under 200 rpm shaft speed upto its maximum 2000 rpm speed is reached. The electric generator production power, equal to 2KW can be used to charge the batteries or supply electricity for other internal applications. For a normal sedan requiring power of 50KW, it shall take 50hrs to charge the vehicle in motion. The initial results obtained shows that the employment of a car alternator as the electric generator in a wind turbine set is possible.
Rabiul *et al.,* (2015)[13]	3 blades made of stainless steel 2 rubber belts. permanent magnet. (PMDC) motor as generator HAWT Turbine	The VMWT designed in a way to agree with the aspects of light weight, high rpm, low cost. A wind turbine was placed on a running vehicle and an airfoil coming from the back or opposite direction. A generator was placed on the roof or back luggage area of the vehicle and is linked with a turbine shaft with the help of a belt. The output terminal of the generator is attached to a storage device like batteries.	From the experiment it can be concluded that, by VMWT upto 200W of electricity is accessible from a single vehicle.
Ferdous.*et al.,* (2011)[14]	HAWT with 2 blades (lift type), AC generator with 8 poles, 3 phase AC to DC converter.	Vehicle was powered by a 1.5 kW DC motor, it has to move at a velocity of 54 km/h. The wind turbines were kept in such a way that the axial forces or thrusts of the wind on the turbines are 180 degrees apart from each other. When the vehicle moves, the cuk converter gives a constant 60V at the output. The current of the converter fluctuates with the fluctuations of the speed of the vehicle or the rpm speed of the turbine. The compatibility of the wind turbine model created is simulated and checked using ANSYS CFX.	It was found that the vehicle moving at a speed of 54 kmph produces a power of 360W which is 180W per turbine. This amount of power was provided back to the battery when the vehicle was in motion. In terms of mileage, it increased the mileage by 24%. The simulation results showed that both the models prepared experience similar drag and the turbines in them are arresting some parts of the energy which has already been utilized by the vehicle to prevail the aerodynamic drag.
Thomas *et al.,* (2002)[19]	Generator, Rotor blades, Vehicle (trucks), Turbine, Belt, AC/DC converter.	The vehicle which was in motion at moderate to high speed applying force against the wind deflector which was placed on the truck, cab, or tractor. The wind energy fuel was then administered towards the face area of a propeller, spinning a turbine, which then operated the generator in the vehicle to produce electricity.	To generate an adequate amount of electricity to power the entire vehicle, very large rotors with diameters of 40-50 meters were required to run with wind speed of 45 kmph. wind energy fuel generated in the experiment was enough to power a hybrid vehicle, but still not able to fully power an electric vehicle

Vaibhav *et al.*, (2018)[21]	CPU cooling fan (5W, 0.3A), Bridge rectifier, Capacitor, Integrated Circuit (IC), Charging pin adapter, Connecting wires	CPU cooling fan acts as a Wind-turbine as well as a generator. Connecting Wires from the fan were connected to the rectifier which acts as the input to the control circuit with a female adapter at the output. The assembly was mounted at the front near the number plate of the vehicle.	Case 1: velocity=5.56 m/s, voltage measured= 7V, current measured=0.05A, power=0.35W. Case 2: velocity=11.11m/s, voltage measured= 23V, current measured=0.15A, power=3.45W. Case 3: velocity=13.89m/s, voltage measured= 32V, current measured=0.18A, power=5.76W. Case 4: velocity=16.67m/s voltage measured=40V, current measured=0.2A, power=8W.
Mulla *et al.*, (2017)[10]	Fan, Alternator, Battery 12V (lead acid), Power converter, Motor 12V.	When the vehicle was running, the fan starts rotating. Then when the desired amount of wind flow was available the alternator starts to produce power. Required power was then given to the power converter. The converter power was transferred to the motor rotor which was connected to the shaft connected to gear, which started to rotate the car.	The wind car was not practical, due to high air resistance. The amount of power required to maintain a persistent velocity should be more than the aerodynamic drag, road drag, and rolling resistance, during the motion of the vehicle.
Sham (2011)[16]	vertical axis wind turbine; Top plate, Top deflectors, Front deflectors, Side deflectors, Rear deflectors, Anemometer, Generator.	The wind turbine was placed above or on the roof of the automobile to get the maximum high speed wind. The wind turbine was placed in the horizontal plane to minimize the air resistance. The wind WECS was constructed in such a way that the air that enters the wind turbine rotates the blades in anti-clockwise direction, and the air that enters through the left side is deflected by 20 degrees so that it also rotates the blades in anti-clockwise direction.	Tested with some weights on the blades to increase rpm. Case 1. speed=11.4 kmph; air speed=189 kmph turbine rpm=61.059 Case 2. speed=11.5kmph; air speed=192kmph, turbine rpm=61.0594 Case 3. speed=11.5kmph; air speed=191kmph, turbine rpm=61.59 Case 4. speed=11.5kmph; air speed=192kmph, turbine rpm=61.594. Case 5. speed=11.5kmph; air speed=195kmph, turbine rpm=61.5946. The results obtained were convincing enough to conclude that wind turbine has a workable product.

Dare *et al.*, (2012)[1]	3 bladed vertical axis wind turbine, 6 pole induction generator, Gearbox of gear-ratio 3:1.	The vehicular wind energy fuel converter or Wind-turbine used was a three-bladed, drag type vertical axis wind turbine that generates electrical energy from the wind flowing over a vehicle in motion. The device or wind energy fuel converter is a packed device which only has the inlet and outlet window. The tapered inlet window is designed in such a way so that the inlet wind is focused on the blade so that the wind velocity is also amplified to about 1.4 times before it strikes the blades. The external shell of the device is streamlined to reduce the drag.	The results were provided with the help of a graph. The graph was drawn against approximated power (kW-h) against vehicle speed(m/s), which is like a steep slope. The energy requirement of most electric vehicles ranges between 12-37 kW-h. Electric vehicles have a battery capacity of 200 kW and needed electrical energies between 26-27 kW-h to work. From the experiment they got the wind energy fuel converter system or WECS develops 30.5 kW-h at 7m/s, and energy of 28.8 kW-h at 6m/s, this would charge the battery in about 7-8 hours of continued driving.
Hossain *et al.*, (2016)[8]	Rotor, Fixed pump, Doubly fed induction generator, Accumulator, DSP controller, MATLAB Simulink.	The control system algorithm was designed in Simulink, it was designed properly to make sure that the optimal operation of the whole system, and rooted on FLC with stator flux orientation and the MPPT technique. The output power was levelled out despite wind variations, which was practically not the case but generally required in a grid linked to a wind farm. This strategy can decrease the stress in the pitch control system by regulating the value of power coefficient.	The wind turbine cannot fully charge the vehicle while in motion but can certainly increase the mileage, and thus save a lot of money. The cost of 20 years of running a car using conventional energy is $33k dollars and the cost of a car is $25k, which amounts to $58k. The wind powered car clearly showed savings of $15k, and in addition $13k, as the turbine can also be removed once the turbine system placed or fixed, therefore, saving a total of $28k for a functioning car in 20 years.
Zahir Hussain *et al.*, (2020)[7]	35Ah, 12V battery. wind turbine, VAWT, 12V DC generator, Power boost converter (DC),	VAWT and required amount of blades were calculated by CATIA V5 software. The VAWT was designed to produce 0.5 kW of energy when the vehicle is moving at a speed of 40-60 kmph.	It was found that the suggested design of the battery charging system can produce the required amount of power output for charging the batteries which was used in electric vehicles in a well-organized manner.
Su-Huei *et al.*, (2014)[17]	wind turbine, material required to make shroud (steel, aluminium, carbon-fibre)	The older model of shroud was shown theoretically to increase power amplification by a factor of about 4. For the new shroud design, the model was replicated, but the modification done was by changing the already in-use flange design to a curved flange which has a concave curvature inwards with radius of approximately 66mm.	From ANSYS CFD simulation it was observed that just from changing the flange design: 1. The highest wind-speed ratio of the new model was 2 times that of the conventional shroud model. 2. A more negative pressure coefficient was found for the new modified model, it means a lesser pressure, which is more conductive for the advancement of the coming air. 3. The power coefficient of the modified model was about 1.48 which is more than the bitz limit which is 0.59. 4. Mechanical power was also shown to be improved by a factor of 3.

Mouna *et al.,* (2016)[9]	Wind turbine, (DFIG) Doubly fed induction generator, Converter side grid, MATLAB Simulink.	The general structure of the DFIG orientation was made in the Simulink and checked for the performance. The turbine was connected to the multiplier shaft which in turns increases the speed of the rotor i.e., DFIG, the control then flows to the power converters which connects the rotor to the grid through inverters and rectifier.	The results obtained by Simulink are as follows: The determined speed and the power coefficient were shown not to vary a lot of values. The wind power which was apprehended follows its ace reference. The speed of the DFIG was due to the wind causing the rotation. The forms of the electromagnetic torque of the DFIG and its ideal form, were apparently identical. The configuration of the components of the stator flux orientation conveys a fine flow to make sure control was nicely disassociated from the DFIG.
Nannoori and Nagarju, (2015)[11]	Wind turbine, DC generator, voltage regulator, rechargeable battery, DC motor driver, DC motors, RF transmitters, Crystal Oscillator.	Horizontal-axis wind turbines or HAWT have the major rotor pole and electrical generator at the peak of the tower. In the suggested model the face of the wind turbine can be controlled with respect to the wind using control buttons.	The systematic study of each part of the modified wind turbine has granted an initial knowledge of a new possible technology of executing an integrated wind powered electric vehicle with wireless RF technology. This experiment has provided a chance for system modification and environmental friendly transportation. This practical improvement along with the need for efficient wind energy fuel based travelling vehicles created faster, more precise and more smart power control algorithms.
Gideon Quartey (2014)[4]	The rotor, Main shaft, Main bearing coupling, Top shroud, Generator, Base shroud, Exhaust safety, Inlet safety guard.	The wind goes into the diffuser shroud at the cove to the turbine, getting to the outlet of the turbine. The Rotor consists of 3 blades, it gathers the kinetic energy in the wind and transforms it into rotational motion. Main Shaft then transfers the rotational energy of the propeller to the generator with the aid of the bearings. Generator then transforms the mechanical energy to electrical energy.	The wind turbine was designed in a way to draw out the maximum amount of energy from the wind to power the automobile. From the conceptual calculation on the power produced from the wind, it was found that a significant amount of electrical power (about 3.26kW) was replenished to the batteries when the car is moving at a speed of 120 kmph.
John *et al.,* (2011)[6]	Toyota prius, wind turbine (skystream 3.7) 1.8kW, Hymotion A123 L5 Lithium Ion Batteries.	The turbine used was a top of 45 ft pole, with blade diameter of 12ft. Over the course of the year it was observed that wind turbines generated less electricity during summer and more in winter. The wind turbine produced 1442 kWh.	It was found that the wind turbine was capable of producing adequate electricity to balance the electrical utilization of hybrid vehicle. However, as the result shows that the wind turbine was not able to charge the vehicle, it was very possible that on daily, monthly, or seasonal level, the wind power apprehended may have been inadequate to provide sufficient electricity to the hybrid vehicle as needed at times.

Fuad *et al.*, (2020)[3]	Wind turbines, DC power chargers, AC-DC-AC Converters.	The wind-powered electric vehicle charging stations have limitations such that they were strongly dependent on the accessibility of persistent power provided from wind turbines, which is not normally the case in real life. Comparing this with an immediate charging scenario, the wind powered charging stations were undesirable. In this study, direct wind-to-EV charging using DC fast-charging technology was used due to the notable decrease in power transforming stages.	Turbine name: no16, Height: 134m, Cut in: 3m/s, Rated: 10m/s, Cut out: 20m/s, Power: 3300kW, M4 tower data 1 min: 9.41%, 2 min: 14.34%, 3 min: 18.35%, M2 tower data 1 min: 5.22%, 2 min: 8.28%, 3 min: 9.78%, Turbine name: no128, Height: 99m, Cut-in: 3m/s, Rated: 10m/s, Cut out: 25m/s, Power: 2200kW, M4 tower data 1 min: 14.96%, 2 min: 18.73%, 3 min: 22.2%, M2 tower data 1 min: 6.86%, 2 min: 8.97%, 3 min: 10.21%, And similarly more such turbines.
Syed *et al.*, (2019)[18]	Medium scale wind turbine, PHEV Battery, DC/DC buck boost converter, DC/DC Boost Converter, DC/AC Main Converter, Permanent Magnet Synchronous Generator (PMSG)	The MSWT was coupled with PMSG to generate power from the available wind energy fuel. The energy storage system was connected to a DC bus which was used for charging and discharging. The proposed charging system was based on sensing variations in DC-link voltage. Whenever the wind speed changed or RL occurred, the DC-link voltage changed. Based on the changes in the DC-Link voltage, the loading condition of the distribution transformer was scheduled for electrical hybrid vehicle charging/discharging.	1. Charging dock number: 1, Car number: 1, Minimum State of charge: 25%, Maximum State of charge: 85%, Charging time: 1 hour, Avg % change in cars's SOC= 60%, 2. Charging dock number: 2, Car number: 2, Minimum State of charge: 25%, Maximum State of charge: 85%, Charging time: 1 hour, Avg % change in cars's SOC= 60%, 3. Charging dock number: 3, Car number: 3, Minimum State of charge: 30%, Maximum state of charge: 90%, Charging time: 1 hour. Avg % change in cars's SOC= 60%.
Andrew (2009)[2]	1Turbine along with Generator, Charge Regulator, Wind Tower, Lead acid battery bank, DC Power centre, Inverter, Simulink	Power from the wind was transferred to the turbine, which then transmits the power to the generator, where it was transformed into DC electrical energy. In this a charge controller restricts the current flow from the generator to batteries and other parts of automobiles to prevent damage to other systems. The entire system was DC until power arrives to the inverter. The electrical power output was calculated from the input wind speed. Load from the car was 0-2 kW. This load was deducted from the power yield of the turbine.	From the simulation for 6 months it was established that the battery's state of charging reduced to below zero often due to low wind speeds. Below zero SOC shows that the system is not able to charge the vehicle as required. It was found that the turbines could have produced extra energy than was required, but much of it was only accessible to the system when it was not able to utilize it. The battery capacity would have to be improved to 532.8 kWh for the system to be able to meet the vehicle's energy requirement. This was a very substantial increase compared to 44.4 kWh capacity considered and would cause a drastic difference to the price, size, and mass.

results derived from design and fabrication on various types of automobiles using wind energy fuel.

3.0 Conclusions

It was found that wind energy fuel can certainly power automobiles, but there still exist limitations i.e. it cannot fully power a moving vehicle, rather it can improve automobile's mileage by some extent improving efficiency of WECS is one of the major challenge we face today for it to be of any significant power source. research is still going on in this field.

- If the velocity of the wind increases, the overall efficiency also increases.
- In some cases, it was found that WECS increased the mileage of the automobile by upto 30%.
- Use of diffuser shrouds can be used to improve the efficiency of the WECS.
- Using vertical-axis wind turbines reduces wind resistance by a significant amount.
- Savonius type vertical-axis wind turbines have shown efficiency of about 21%-35%.
- Car alternator as an electric generator is also possible in wind turbines for automobiles.
- Wind energy fuel converter systems integrated with solar panels or solar energy converter systems may charge the whole automobile without any external source.

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