Electric Vehicles: How Clean Are They?

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The government of India, as a part of its commitment to reduce greenhouse gas emissions and also in view of the recurring episodes of high air pollution in major cities, has an ambitious plan to shift from petrol/diesel vehicles to electric vehicles for both public and private use by 2030. A similar trend is seen in many other countries of Europe, USA, Germany, etc. What then is an electric vehicle and how clean is it?

An electric car looks almost like a petrol or diesel car. However, if you observe more closely, you will find that while driving, the electric car produces much less noise and more importantly does not produce tailpipe emission. In fact, it does not have a tailpipe at all.

Under the bonnet you will find some more tell-tale signs: instead of a huge internal combustion engine with its fuel lines, exhaust pipes, coolant hoses and intake manifold, all you see is an electric motor and its controller. Then there is no petrol tank at the back. It is replaced by a traction battery pack under the passenger seat.

How does an Electric Car Work?
All cars are energy conversion devices – converting potential energy stored in the fuel to kinetic energy to drive the wheels. In a conventional vehicle, the fuel is petrol or diesel. When the fuel is mixed with oxygen and burned inside the Internal Combustion Engine (ICE), it releases the energy locked in the hydrocarbons of the fuel as heat, which pushes the pistons to turn the wheels of the car.

The burning process produces a number of chemical compounds like oxides of nitrogen, sulphur, carbon dioxide etc. which are released to the environment through the tailpipe. These have adverse effect on the environment (global warming) and on human health.

The workhorse of an electric vehicle is its electric motor. It converts the chemical energy stored in the battery to mechanical energy to turn the wheels of the car. The process takes place electrochemically, without any burning of the fuel and hence no emission of any kind. Thus, an electric car is considered “clean”.

The principle of an electric motor is simple. Place a copper wire in a magnetic field and pass an AC current through it. The AC current induces a varying magnetic field in the copper wire due to which it experiences a force or torque. If the copper wire is in the form of a loop, then the two sides of the loop, which are at right angles to the external magnetic field experience forces in the opposite directions, making the loop rotate. Attach a shaft to the loop, you have a rotating axle.

In an actual electric motor, the rotating part is the rotor (also called armature). Rotor has conducting coils.
It is enclosed in a stator, which carries a magnet. When electric current flows through the rotor coils, the induced magnetic field interacts with the stator magnetic field to produce a torque.

The rotor also carries a commutator, a device to reverse the direction of the current flow in the rotor to flip the induced magnetic field with respect to the stator magnetic field. This keeps the rotor from getting locked in one position but rotating continuously as long as the current is flowing through it. This power is transferred to the drive wheel to drive the car. Both AC and DC motors can be used.

One of the biggest differences between a petrol vehicle and an electric vehicle has to do with the drive train – that is the transmission, gear and clutch assembly. A petrol car has a multiple speed gearbox and a clutch to engage them while driving. This is because most internal combustion engines cannot operate below about 750 RPM, which is quite high to start a car from standstill. So, a step-down gear is required to adopt the high-speed engine to the stationary drive wheel.

Secondly, the range of efficient operating RPM of an ICM is very narrow – between 2000 and 4000 RPM. So, a multiple gear system is required to convert this narrow power range of the engine to a wide range of vehicle speeds.

The situation is quite different in an electric motor. First, it delivers maximum usable steady torque, right from the lowest RPM at the start to as high as 20,000 RPM. This range comfortably covers all the possible speed ranges of the car, including the start from standstill. So, instead of packing the car with a multiple gearbox, vehicle designers pick out a transmission with just one gear ratio that provides a good compromise for acceleration and top speed.

### The Battery Pack
Where does the motor get its energy from? It is from the traction battery pack. It replaces the petrol tank in a conventional vehicle. The electrical energy from the battery pack consisting of several cells is delivered to the motor through a controller which controls the motor’s speed and torque.

The present generation of electric cars run on lithium-ion batteries, similar to ones used in mobile phones and laptops, but much bigger in size. When fully charged, it will have a driving range of 80 to 200 km depending upon the power of the battery and the size of the car. When depleted, it can be recharged.

To accelerate the car, as in a conventional vehicle the accelerator pedal is pressed. The accelerator is connected to a potentiometer which signals the motor controller on how much power to be supplied to the motor. When there is no pressure on the accelerator, the power delivered to the motor is zero. So when the vehicle is idle, say at a traffic signal, no electrical power is being processed. That is, no fuel is used unlike in a petrol engine.

An electric car offers another advantage. In a petrol vehicle, when the brake is applied, it opposes the rotation of the wheel and its kinetic energy is wasted as heat. However, in an electric motor, when the brake is pressed, the electronic circuits cut the power to the motors. Now the kinetic energy and momentum of the vehicle make the wheels turn the motor and the torque is reversed through a complex switching system. The reverse torque slows down the vehicle and at the same time, the motor works as a generator producing electric energy instead of consuming it. Thus, part of the kinetic energy lost in the process of slowing down is thus regenerated and fed back to the battery pack, extending its driving range. This is known as ‘regenerative braking’.

About 8 to 25 percent, depending upon the driving conditions (particularly in urban areas with more frequent stop-and-go) is restored in this process. However, mechanical braking system is still required to bring the vehicle to a quick standstill in a panic situation and hold there.

### Zero Emission?
Since an electric vehicle has no tailpipe emission it does not require any emission checks. At the first sight, they appear to be completely green and even have been labelled as ‘zero emitting vehicles’. Are they really so? The answer is both ‘yes’ and ‘no’.

It is true that the electric car is pollution-free in the locality where it is driven, but may not be so at the global level. For recharging the battery of an electric car about 20 to 30 kWh of electrical energy is needed and it has to be derived from the electricity grid in the area. The amount of global warming emissions produced in generating
this electricity has to be considered in evaluating the overall impact of the electric car on the environment.

The Union of Concerned Scientists (UCS) – an organisation in the USA has evolved methods of evaluating the environmental impact of electric vehicles vis-à-vis conventional vehicles, by developing a standard known as CO₂e – “Carbon dioxide equivalent”.

Electricity is generally produced using various technologies – burning fossil fuels like coal and natural gas, nuclear reactors and renewable energy sources such as water, wind and Sun. Though the renewable energy sources are known to be clean, because of technical reasons their contributions in the total electricity generation in any country is still small (except for a few countries like the Netherlands).

Hence, most of the electricity is still generated by burning fossil fuels, which emit significant quantities of greenhouse gases that have different potentials for global warming. Carbon dioxide, however, is the most common among them. For purposes of comparison, the UCS “converts the global warming potential of all emissions to units of carbon dioxide equivalent or CO₂e – the amount of carbon dioxide required to produce an equivalent amount of global warming”.

This can be used to compare the global warming potential of gasoline car emissions with emissions from the electricity grid. To estimate the CO₂e of an electricity grid, emission from all stages from mining the fuel, its transport to the power station, burning the fuel to generate electricity and transmission loss from the power station to where the vehicle is recharged all will be taken into account.

Similarly, to calculate the CO₂e of a gasoline vehicle, emission from various stages of fuel production to delivery to the petrol pump and also the CO₂e of the various greenhouse gases emitted per mile by the vehicle during driving are considered. In addition, the CO₂e of pollution caused during vehicle manufacturing, battery manufacturing and final disposal of the vehicle also will be taken into account.

Production of lithium-ion batteries is energy and resource intensive. Based on these parameters the UCS has evaluated the life-cycle global warming emissions from manufacturing, use and disposal of gasoline and electric cars. While a mid-size petrol-driven vehicle emits nearly 400 grams of CO₂e per mile during its lifespan, it is about 200 grams of CO₂e for a similar electric car.

Similar comparison holds for full-sized cars. (Calculations are based on the average American grid electricity mix in which fossil fuels constitute about 64 percent. In India about 80 percent of electricity comes from fossil fuels).

For both types of cars, the major portion of CO₂ equivalence arises from the operational stage. While in the case of conventional cars it is due to burning the petrol directly, for an electric car it comes from the use of grid electricity for recharging the battery pack. This means that while an electric car is not entirely a zero emission vehicle, it is still far cleaner than a petrol vehicle.

With the global tendency to move away from fossil fuels to renewable energy resources to generate electricity, this comparison becomes even more favourable to electric vehicles in due course.
As of January 2018, the Bengaluru Metropolitan Transport Company has released a tender for the supply of 150 electric buses. The Energy Efficiency Services Ltd, a Government of India unit, has ordered 10,000 electric vehicles from Tata Motors for use in government offices.

The Future

Though the running and maintenance cost of an electric vehicle is much lower than its petrol counterpart, the weakest link in an electric vehicle is the traction battery. Presently lithium-ion battery packs, which provide a DC voltage up to 500 V and a power rating of anything from 18 to 50 kilowatt-hours or even more, are used. They cannot store as much energy as a petrol tank.

Depending upon the model of the car, such batteries can provide a maximum driving range of about 250 km. Though this range is quite sufficient for most city drives, it poses problems for long distance and high way driving. Though a typical household electrical supply can be used to recharge the battery, it takes seven or more hours to recharge.

Recharging stations where the battery can be quickly recharged have to be established on a nation-wide basis like the existing petrol pumps. One of the presently available solutions for the problem is the plug-in hybrid car. It will have both an electric motor with a rechargeable battery and a gasoline tank and internal combustion engine. The idea is that when the battery is down, the driver need not panic, but switch over to the petrol mode.

However, a plug-in-hybrid will have CO₂ equivalence in between a gasoline car and a battery car. Moreover, the batteries are quite expensive at present. The cost is expected to fall as production increases.

Manufacturers are working on alternatives to lithium-ion batteries like nickel metal hydride (NiMH), lithium-nickel-manganese-cobalt, lithium-cobalt batteries, which can have a higher charge density providing a longer range per charge (comparable to a petrol car with full tank) and also recharged faster. A Japanese automaker plans to release by 2022 electric cars that can run 240 km on a single 15-minute charge.

Another promising approach is the development of hydrogen fuel cells in which hydrogen and oxygen undergo chemical reaction to produce electricity. The waste product is just clean water. A fuel cell can provide a much larger driving range and replacing hydrogen fuel cells takes only a few minutes.

To encourage development of electric vehicles the government has announced an incentive to buy electric vehicles for public use under a programme called Faster Adoption and Manufacturing of Electric vehicles in India (FAME-India). Under the scheme, eleven cities (New Delhi, Ahmedabad, Jaipur, Mumbai, Lucknow, Hyderabad, Indore, Kolkata, Jammu, Gauhati, and Bengaluru) have been selected for an incentive of Rs. 437 crores each.

Many states are already on the go. Delhi is already running electric buses on a trial basis and now has decided to order for 500 electric buses. Himachal Pradesh also has been running electric buses in its hilly areas. As of January 2018, the Bengaluru Metropolitan Transport Company has released a tender for the supply of 150 electric buses. The Energy Efficiency Services Ltd, a Government of India unit, has ordered 10,000 electric vehicles from Tata Motors for use in government offices.

On the manufacturing side, Hyderabad-based Goldstone Infratech has announced its plans for the manufacture of 500 electric buses by mid 2018. In addition, a number of other auto manufacturers like Renault, Hyundai, Mahindra, Maruti Suzuki, Nissan, Tesla, etc. have plans to release electric cars to the Indian market. Mahindra has already introduced four models of electric cars on Indian roads.

Two- and three-wheelers are not far behind. Right now the number of electric vehicles is still small compared with the petrol/diesel vehicles on the road, but the race is clearly on. The Society of Indian Automobile Manufacturers says that by 2030 about 40% of all vehicles in the country would be electric and this would go up to 100% by 2047.

With all these future developments, petrol vehicles might one day become museum items.