UNIT-I SYLLABUS

Introduction of Electric Vehicles: Concept of Electrified transportation, Past, present status of electric vehicles, Recent developments and trends in electric vehicles, Comparison of EVs and IC Engine vehicles, Understanding electric vehicle components, Basic EV components and architecture, Autonomy and vehicle computing needs.

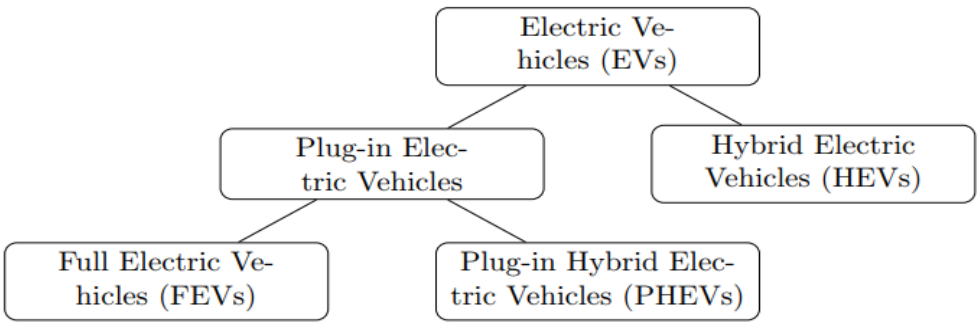
Introduction of Electric Vehicles

Electric vehicles (EVs) are vehicles that are powered by an electric motor rather than a conventional internal combustion engine. They are charged by plugging them into an electrical outlet or charging station, and their energy is stored in a rechargeable battery. EVs emit less greenhouse gases and air pollutants than traditional gasoline-powered vehicles, and they are generally more energy efficient. However, their driving range and charging infrastructure can be a limitation compared to gasoline vehicles.

- Electric Vehicle (EV) propelled by electric motors and uses electrical energy stored in batteries.
- Unlike vehicles with combustion engines, electric vehicle do not produce exhaust gases during operations.
- An EV is a vehicle that no longer relies solely on an Internal Combustion Engine (ICE) as the only propulsion mechanism, but rather uses an electric drive system as a replacement, or to enhance, the ICE.

Roughly speaking, three types of electrically propelled vehicles can be distinguished.

- A Full Electric Vehicle (FEV) runs solely on an electric drive system. As with PHEVs their batteries are large and can be recharged in charging stations or at home. Since there are no pollutants released while driving, these vehicles are often marketed as zero-emission vehicles.
- Of these three types, we shall distinguish PHEVs and FEVs from HEVs, and we shall denote the former as plug-in EVs, to emphasize that they continuously have to recharge their batteries.



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- **A Hybrid Electric Vehicle (HEV)** combines an ICE and an electric motor within the drive train. Mostly, the electric motor supports the ICE for fuel economy and/or performance.
  - The vehicle is then either propelled by the combustion engine or the electric drive.
- **A Plug-in Hybrid Electric Vehicle (PHEV)** is a vehicle equipped, in general, with a larger battery compared to HEVs, that allows recharging of the battery via home outlets or at charging stations.
  - While in most cases both the electric drive and the ICE are able to propel the vehicle, some vehicles use solely the electric drive.
  - In this latter case the ICE can be used to recharge the battery or directly produce electricity for the electric drive.

Also, in most cases PHEVs can be used in a full electric mode if there is enough energy stored in the battery. This allows one to select when and where to release pollutants.

Working of EV

- An electric car is powered by an electric motor instead of a petrol engine.
- The electric motor gets energy from a controller, which regulates the amount of power—based on the driver's use of an accelerator pedal.
- The electric car (also known as electric vehicle or EV) uses energy stored in its rechargeable batteries, which are recharged by common household electricity.
- Thus an electric vehicle will have three basic components :
  - Energy Storage Unit
  - Controller
  - Propulsion system

The energy storage unit will have a way to store power. A chemical battery is the most common energy storage technology currently, although it can be different - for example - A fuel cell (which gets its electricity from hydrogen rather than a battery pack), can be used instead of a chemical battery as the energy storage unit.

The controller acts as a pipeline or gateway to the electric motor.. The controller will do other things too - it moderates the power, will also act as a converter - converts power from DC to AC, or it might also increase or decrease the amperage etc. The controller is the brains of the system.

The electric motor, which is the propulsion system, converts the electric power and converts this into physical energy for movement.

The whole system is a much simpler, more efficient device than the combustion engine found in most cars, enabling you to get the most mileage for your charge.

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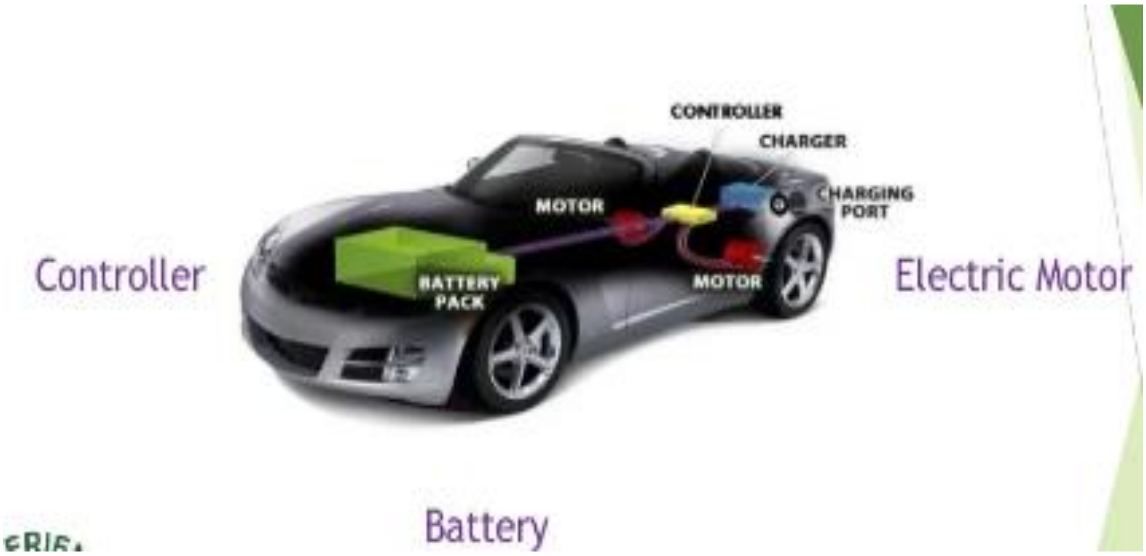

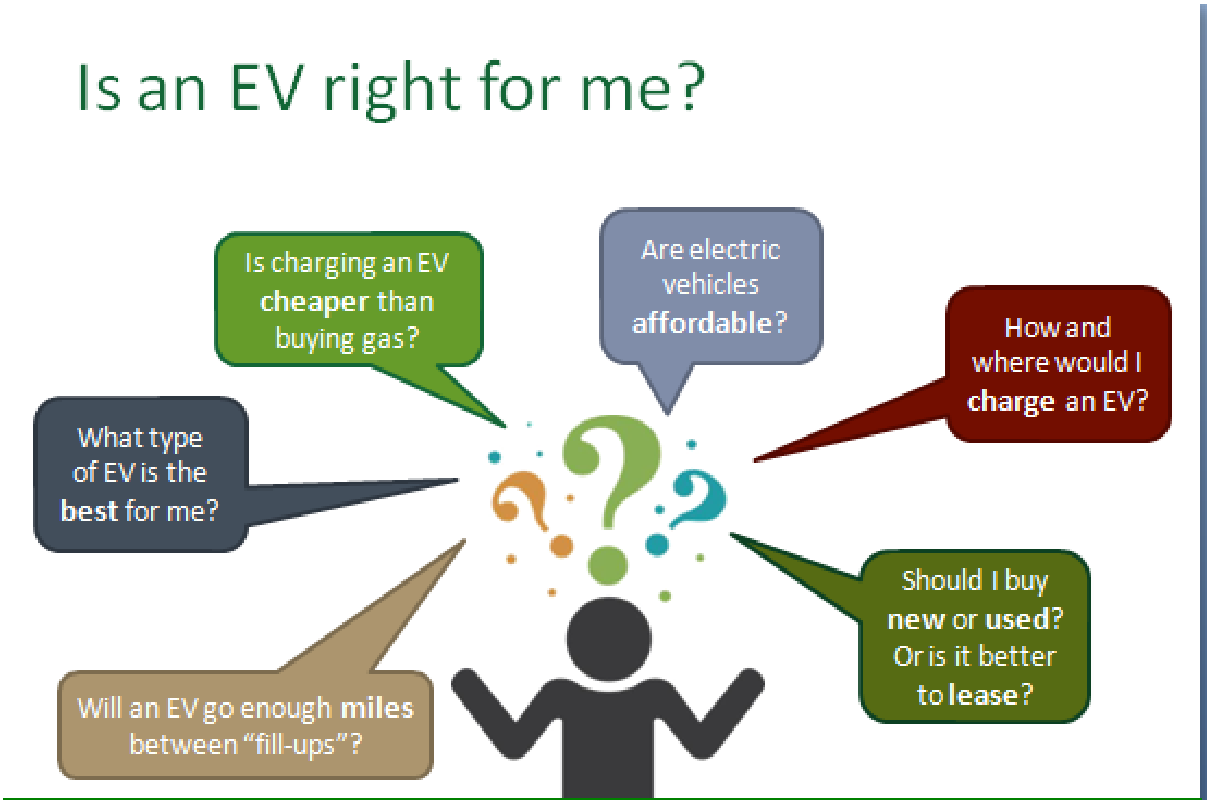

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Concept of Electrified transportation

- Transportation is currently the least-diversified energy demand sector, with over 90% of global transportation energy use coming from petroleum products.
- For more than a century, petroleum fuels have been relied upon to move people and goods within and between towns and cities, and on roads, railways, farms, waterways, and in the air.
- Various attempts have been made to diversify the transportation energy mix, but global dependence on petroleum for transport remains .
- In recent years, the electrification of transport has emerged as a trend to support energy efficiency and CO2 emissions reduction targets.
- Relative to their internal combustion vehicle (ICV) counterparts, electric vehicles (EVs) be they trains or cars, have a greater "well-to-wheel" energy efficiency.
- They also have the added benefit of not emitting any carbon dioxide in operation and rather shift their emissions to existing local fleet of power generation technology.
- Public health benefits and the faster the transition occurs, the faster those benefits are realized by our communities.
- When those vehicles are powered by clean electricity, they can help us make substantial progress in curbing carbon pollution to address climate change.
- Transportation electrification is a key strategy in the fight to avoid the worst impacts of climate change.
- Increasing the number of electric vehicles on the road is key in decarburizing our transportation sector as we continue to transition away from fossil-fueled electricity.

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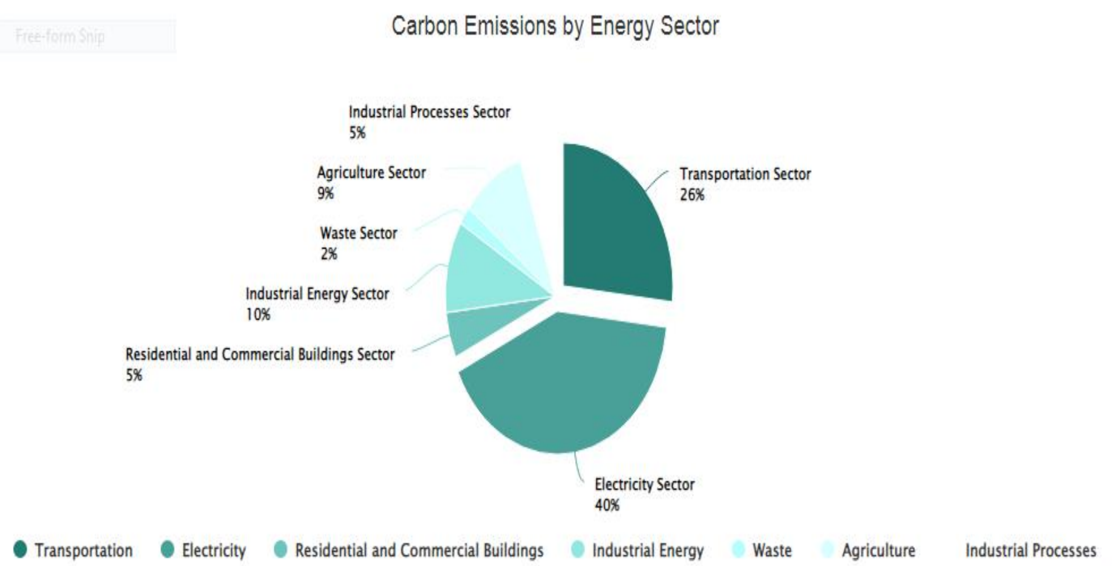

Environmental Impact and History of Modern Transportation

- The development of internal combustion engine vehicles, especially automobiles, is one of the greatest achievements of modern technology.
- Automobiles have made great contributions to the growth of modern society by satisfying many of its needs for mobility in everyday life.
- The rapid development of the automotive industry, unlike that of any other industry, has prompted the progress of human society from a primitive one to a highly developed industrial society.
- The automotive industry and other industries that serve it constitute the backbone of the word's economy and employ the greatest share of the working population.
- However, the large number of automobiles in use around the world has caused and continues to cause serious problems for the environment and human life.
- Air pollution, global warming, and the rapid depletion of the Earth's petroleum resources are now problems of paramount concern.
- In recent decades, the research and development activities related to transportation have emphasized the development of high efficiency, clean, and safe transportation.
- Electric vehicles, hybrid electric vehicles, and fuel cell vehicles have been typically proposed to replace conventional vehicles .

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- The problems of air pollution, gas emissions causing global warming, and petroleum resource depletion are discussed here.

Air Pollution

- At present, all vehicles rely on the combustion of hydrocarbon fuels to derive the energy necessary for their propulsion.
- Combustion is a reaction between the fuel and the air that releases heat and combustion products. The heat is converted to mechanical power by an engine and the combustion products are released into the atmosphere.
- A hydrocarbon is a chemical compound with molecules made up of carbon and hydrogen atoms.
- Ideally, the combustion of a hydrocarbon yields only carbon dioxide and water, which do not harm the environment.
- Indeed, green plants "digest" carbon dioxide by photosynthesis.
- Carbon dioxide is a necessary ingredient in vegetal life. Animals do not suffer from breathing carbon dioxide unless its concentration in air is such that oxygen is almost absent.
- Actually, the combustion of hydrocarbon fuel in combustion engines is never ideal.
- Besides carbon dioxide and water, the combustion products contain a certain amount of
    - Nitrogen oxides (NO_x),
    - Carbon monoxides (CO), and
    - Unburned hydrocarbons (HC), all of which are toxic to human health.

    - **Nitrogen oxides** (NO_x) result from the reaction between nitrogen in the air and oxygen. Theoretically, nitrogen is an inert gas.
    - However, the high temperatures and pressures in engines create favorable conditions for the formation of nitrogen oxides.
    - Temperature is by far the most important parameter in nitrogen oxide formation. The most commonly found nitrogen oxide is nitric oxide (NO), although small amounts of nitrogen dioxide (NO2) and traces of nitrous oxide (N2O) are also present.
    - Once released into the atmosphere, NO reacts with oxygen to form NO2.
    - This is later decomposed by the Sun's ultraviolet radiation back to NO and highly reactive oxygen atoms that attack the membranes of living cells.
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- Nitrogen dioxide is partly responsible for smog; its brownish color makes smog visible.
- It also reacts with atmospheric water to form nitric acid (HNO3), which dilutes in rain.

- This phenomenon is referred to as "acid rain" and is responsible for the destruction of forests in industrialized countries.
- Acid rain also contributes to the degradation of historical monuments made of marble.

- **Carbon monoxide** results from the incomplete combustion of hydrocarbons due to a lack of oxygen. It is a poison to human and animal beings that breathe it. Once carbon monoxide reaches the blood cells, it fixes to the hemoglobin in place of oxygen, thus diminishing the quantity of oxygen thatreaches the organs and reducing the physical and mental abilities of affected living beings.
- **Unburned hydrocarbons** are a result of the incomplete combustion of hydro carbons. Depending on their nature, unburned hydrocarbons may be harmful to living beings. Some of these unburned hydrocarbons may be direct poisons or carcinogenic chemicals such as particulates, benzene, or others.

Impurities in fuels result in the emission of pollutants. The major impurity is sulfur, which is mostly found in diesel and jet fuel and also in gasoline and natural gas.

Global Warming

- Global warming is a result of the "greenhouse effect" induced by the presence of carbon dioxide and other gases, such as methane, in the atmosphere.
- These gases trap the Sun's infrared radiation reflected by the ground, thus retaining the energy in the atmosphere and increasing the temperature.
- An increased Earth temperature results in major ecological damages to its ecosystems and in many natural disasters that affect human populations.
- Global warming is believed to have induced meteorological phenomena such as "El Niño," which disturbs the South-Pacific region and regularly causes tornadoes, inundations, and dryness.
- The melting of the polar icecaps, another major result of global warming, raises the sea level and can cause the permanent inundation of coastal regions, and sometimes of entire countries.
- Carbon dioxide is the result of the combustion of hydrocarbons and coal.
- Transportation accounts for a large share (32% from 1980 to 1999) of carbon dioxide emissions.
- The transportation sector is clearly now the major contributor of carbon dioxide emissions.

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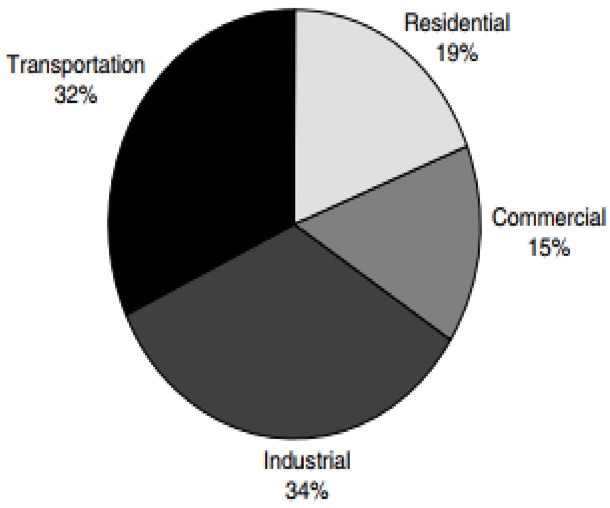
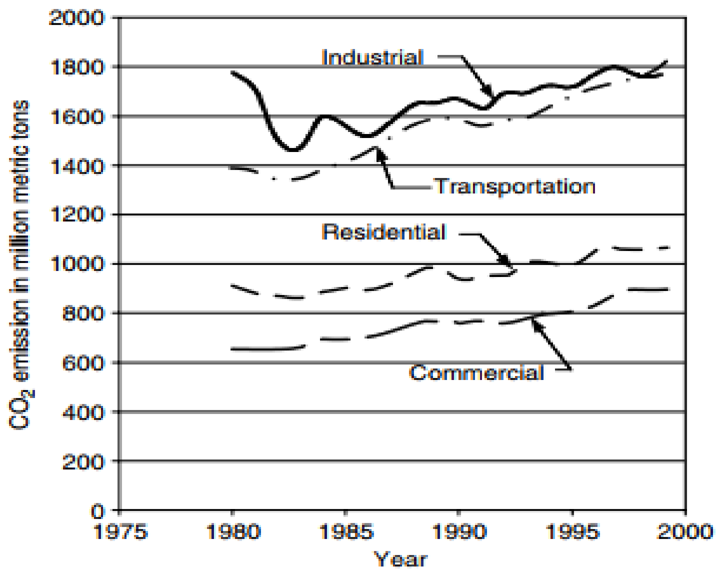
- It should be noted that developing countries are rapidly increasing their transportation sector, and these countries represent a very large share of the world's population.
- The large amounts of carbon dioxide released in the atmosphere by human activities are believed to be largely responsible for the increase in global Earth temperature observed during recent decades.



Carbon dioxide emission distribution from 1980 to 1999



Evolution of carbon dioxide emission

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Petroleum Resources

- The vast majority of fuels used for transportation are liquid fuels originating from petroleum.
- Petroleum is a fossil fuel, resulting from the decomposition of living matters that were imprisoned millions of years ago (Ordovician, 600 to 400 million years ago) in geologically stable layers.
- The process is roughly the following: living matters (mostly plants) die and are slowly covered by sediments.
- Over time, these accumulating sediments form thick layers, and transform to rock.
- The living matters are trapped in a closed space, where they encounter high pressures and temperatures, and slowly transform into either hydrocarbons or coal, depending on their nature.
- This process took millions of years to accomplish. This is what makes the Earth's resources in fossil fuels finite.

Introduction to Hybrid Vehicles

- A hybrid vehicle combines any two power (energy) sources. Possible combinations include diesel/electric, gasoline/flywheel, and fuel cell (FC)/battery.
- Typically, one energy source is storage, and the other is conversion of a fuel to energy. The combination of two power sources may support two separate propulsion systems.
- Thus to be a True hybrid, the vehicle must have at least two modes of propulsion.
- For example, a truck that uses a diesel to drive a generator, which in turn drives several electrical motors for all-wheel drive, is not a hybrid.
- But if the truck has electrical energy storage to provide a second mode, which is electrical assists, then it is a hybrid Vehicle.
- These two power sources may be paired in series, meaning that the gas engine charges the batteries of an electric motor that powers the car, or in parallel, with both mechanisms driving the car directly.
- Consistent with the definition of hybrid above, the hybrid electric vehicle combines a gasoline engine with an electric motor. An alternate arrangement is a diesel engine and an electric motor (figure).
- As shown in Figure, a HEV is formed by merging components from a pure electrical vehicle and a pure gasoline vehicle.
- The Electric Vehicle (EV) has an M/G which allows regenerative braking for an EV; the M/G installed in the HEV enables regenerative braking. For the HEV, the M/G is tucked directly behind the engine. In Honda hybrids, the M/G is connected directly to the engine.

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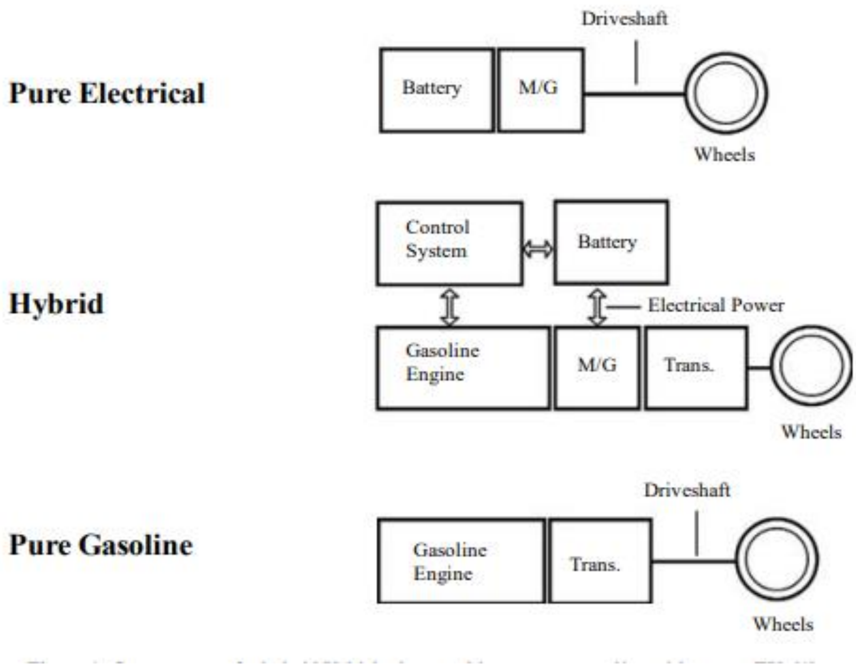
- The transmission appears next in line. This arrangement has two torque producers; the M/G in motor mode, M-mode, and the gasoline engine.
- The battery and M/G are connected electrically.



- HEVs are a combination of electrical and mechanical components.
- Three main sources of electricity for hybrids are batteries, FCs, and capacitors. Each device has a low cell voltage, and, hence, requires many cells in series to obtain the voltage demanded by an HEV. Difference in the source of Energy can be explained as:
  - The FC provides high energy but low power.
  - The battery supplies both modest power and energy.
  - The capacitor supplies very large power but low energy.
- The components of an electrochemical cell include anode, cathode, and electrolyte (shown in fig).
- The current flow both internal and external to the cell is used to describe the current loop.

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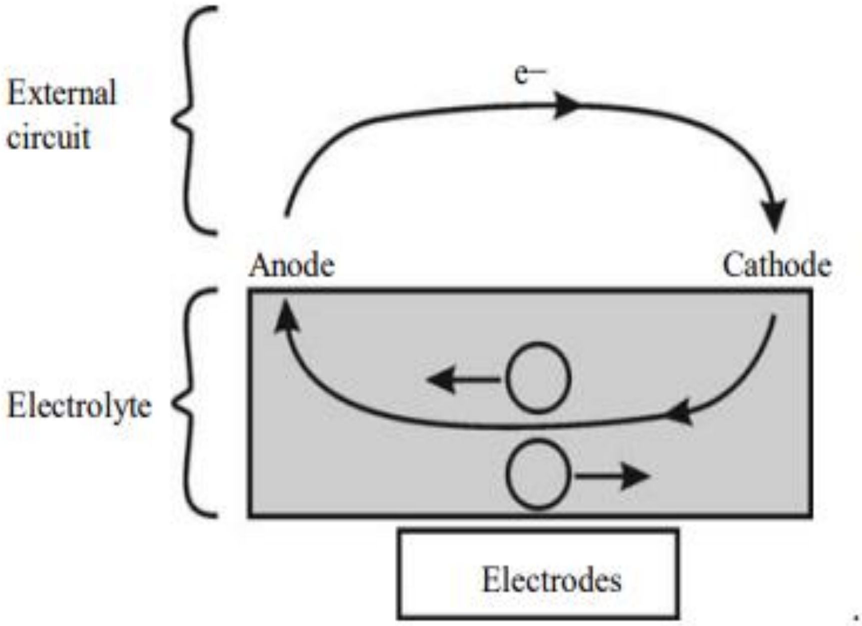

- A critical issue for both battery life and safety is the precision control of the Charge/Discharge cycle. Overcharging can be traced as a cause of fire and failure.
- Applications impose two boundaries or limitations on batteries. The first limit, which is dictated by battery life, is the minimum allowed State of Charge.
- As a result, not all the installed battery energy can be used.
- The battery feeds energy to other electrical equipment, which is usually the inverter.
- This equipment can use a broad range of input voltage, but cannot accept a low voltage. The second limit is the minimum voltage allowed from the battery.

Historical development (root) of Automobiles

- In 1900, steam technology was advanced. The advantages of steam-powered cars included high performance in terms of power and speed.
- However, the disadvantages of steam-powered cars included poor fuel economy and the need to “fire up the boiler” before driving. Feed water was a necessary input for steam engine, therefore could not tolerate the loss of freshwater.
- Later, Steam condensers were applied to the steam car to solve the feed water problem. However, by that time Gasoline cars had won the marketing battle.
- Gasoline cars of 1900 were noisy, dirty, smelly, cantankerous, and unreliable. In comparison, electric cars were comfortable, quiet, clean, and fashionable.

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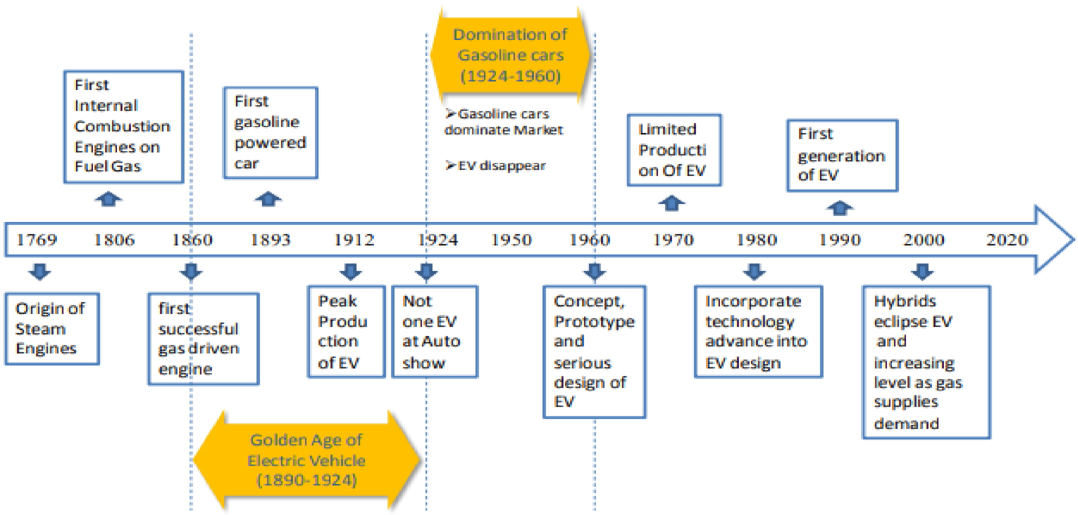
- Ease of control was also a desirable feature. Lead acid batteries were used in 1900 and are still used in modern cars. Hence lead acid batteries have a long history (since 1881) of use as a viable energy storage device.
- Golden age of Electrical vehicle marked from 1890 to 1924 with peak production of electric vehicles in 1912. However, the range was limited by energy storage in the battery. After every trip, the battery required recharging.
- At the 1924 automobile show, no electric cars were on display. This announced the end of the Golden Age of electric-powered cars.
- The range of a gasoline car was far superior to that of either a steam or an electric car and dominated the automobile market from 1924 to 1960.
- The gasoline car had one dominant feature; it used gasoline as a fuel.
- The modern period starts with the oil embargoes and the gasoline shortages during the 1970s which created long lines at gas stations.
- Engineers recognized that the good features of the gasoline engine could be combined with those of the electric motor to produce a superior car.



Modern Period of Hybrid History

- ***1997*** The Audi Duo was the first European hybrid car put into mass production and hybrid production and consumer take up has continued to go from strength to strength over the decades.
- ***2000*** Toyota Prius and Honda Insight became the first mass market hybrids to go on sale in the United States, with dozens of models following in the next decade.

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- Honda Insight and Toyota Prius were two of the first mainstream Hybrid Electric Vehicles and both models remain a popular line.
- ***2005*** A hybrid Ford Escape, the SUV, was released in 2005. Toyota and Ford essentially swapped patents with one another, Ford gaining a number of Toyota patents relating to hybrid technology and Toyota, in return, gaining access to Diesel engine patents from Ford.

Present of Hybrid Electric vehicle

- Toyota is the most prominent of all manufacturers when it comes to hybrid cars.
- As well as the specialist hybrid range they have produced hybrid versions of many of their existing model lines, including several Lexus (now owned and manufactured by Toyota) vehicles.
- They have also stated that it is their intention to release a hybrid version of every single model they release in the coming decade.
- As well as cars and SUVs, there are a select number of hybrid motorcycles, pickups, vans, and other road going vehicles available to the consumer and the list is continually increasing.

Future of Hybrid electric vehicle

- Since petroleum is limited and will someday run out of supply. In the arbitrary year 2037, an estimated one billion petroleum-fueled vehicles will be on the world's roads. gasoline will become prohibitively expensive.
- The world need to have solutions for the "400 million otherwise useless cars". So year 2037 "gasoline runs out year" means, petroleum will no longer be used for personal mobility.
- A market may develop for solar-powered EVs of the size of a scooter or golf cart. Since hybrid technology applies to heavy vehicles, hybrid buses and hybrid trains will be more significant.

The rise & fall of electric vehicles in 1828–1930

- The success of commercialization of EVs depends on the satisfactory tackling of four factors: initial cost, convenience of use, energy consumption, and exhaust emission. Only the latter two have been fulfilled and satisfied so far. Therefore, we need to pay further attention toward the following three fundamental factors:
    - availability of good performance products at an affordable cost
    - availability of efficient and user-friendly infrastructure;
    - availability of a good business model to leverage the cost of batteries.
- In 1801, Richard Trevithick built a steam-powered carriage, opening the era of horseless transportation. After over 30 years of noisy and dirty steam engines, the first battery-powered EV was built in 1834.

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- Over 50 years later, the first petrol-powered ICEV was built in 1885. So, the EV is not new; it is about 50 years older than ICEVs. In the early 1900s, it was even better than the ICEV. Having been out of use for almost 70 years, EVs became popular again in the 1970s. Currently, the EV may become a renewed and popular means of mobility.
- In 1828, a Hungarian, A´nyos Jedlik, invented a small-scale model car powered by an electric motor that he designed.
- In 1835, another small-scale electric car was designed by Professor Stratingh of Groningen, Holland, and built by his assistant Christopher Becker.
- In 1835, Thomas Davenport, a blacksmith from Brandon, VT, built a small-scale electric car. Davenport was also the inventor of the first American-built direct current (dc) electric motor.
- In 1838, Scotsman Robert Davidson built an electric locomotive that achieved the speed of 4 mph (6.4 km/h).
- Between 1832 and 1839, Robert Anderson of Scotland invented a crude electrical carriage.
- Rechargeable batteries that provided a viable means for storing electricity onboard a vehicle did not come into being until the 1840s.
- More practical and successful electric road vehicles were invented by both Thomas Davenport and Scotsmen Robert Davidson around 1842. Both inventors were the first to use the newly invented but non rechargeable electric cells or batteries.
- Frenchman Gaston Plante invented a better storage battery in 1865 and his fellow countryman Camille Faure further improved the storage battery in 1881.
- The last decade of the 19th century was a blooming period in the early development of EVs.
- The Pope Manufacturing Company had produced about 500 EVs of the ‘‘Columbia’’ model by the end of 1898.
- Apart from those EV manufacturers in the United States, the London Electric Cab Company in England was inaugurated in 1897 with 15 taxis.

  Moreover, from 1899 to 1906, in France, Bouquet, Garcin & Schivre (BGS) manufactured various types of commercial EVs, including cars, trucks, buses, and limousines. Because the company designed and manufactured batteries especially for its own EVs, the BGS EV of 1900 held the world’s longest range record of almost 290 km per charge.
- It is also interesting to note that the first vehicle running over the 100-km/h barrier was an EV, namely, the ‘‘Jamais Contente’’ (Never Satisfied), which was driven by Camille Jenatzy, a Belgian.

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- It was a bullet-shaped electric racing car, and it captured the record of 110 km/h on May 1, 1899.
- The years 1899 and 1900 were the high point of EVs in the United States, as they outsold all other types of cars. One example was the 1902 Phaeton built by the Woods Motor Vehicle Company of Chicago, IL, which had a range of 18 miles, a top speed of 14 mph and cost $2000.
- Electric vehicles disappeared by 1935, until their revival in the beginning of the 1970s due to the oil crisis by the boycott of the Middle East.

Recent developments and trends in electric vehicles

In response to the climate cahnge and energy crisis, increased global attention has been directed toward the electrification of transportation systems to develop electric vehicles (EVs) . Currently, there are still a large number of conventional internal combustion engine (ICE) vehicles in operation worldwide, and they consume considerable amounts of fossil fuels. Therefore, the acceleration of the electrification of vehicles is imminent. Pure battery EVs, plug-in hybrid EVs, and fuel cell EVs constitute the "green" EV groups. Plug-in hybrid EVs can be considered a transition model, as they still consume fossil fuels and emit pollutants. Although fuel cell EVs has many advantages, such as high energy efficiency, long cruising range, and fast hydrogen refueling, their technology and market are still very immature. Pure battery EVs are zero-emission vehicles that operate entirely on electricity produced by batteries. With the continuous breakthrough of battery technologies, the rapid construction of charging facilities and people's pursuit of low-carbon travel in recent years, pure battery EVs currently occupies most of the EV market and are well-deserved mainstream models . In this context, all EVs below refer to pure battery EVs only.
Traveller range anxiety , insufficient charging infrastructures and challenging charging time management are the most significant obstacles hindering the development of EVs. Representative emerging EV technologies, including

- **Wireless charging**
- **Smart power distribution**
- **Vehicle-to-home (V2H) and vehicle-to-grid (V2G)**
- **Connected vehicles (CVs) , and autonomous driving**

  Provide new solutions to the persistent problems that plague the development and popularization of EVs and also bring good opportunities for the rapid development of new EV markets.

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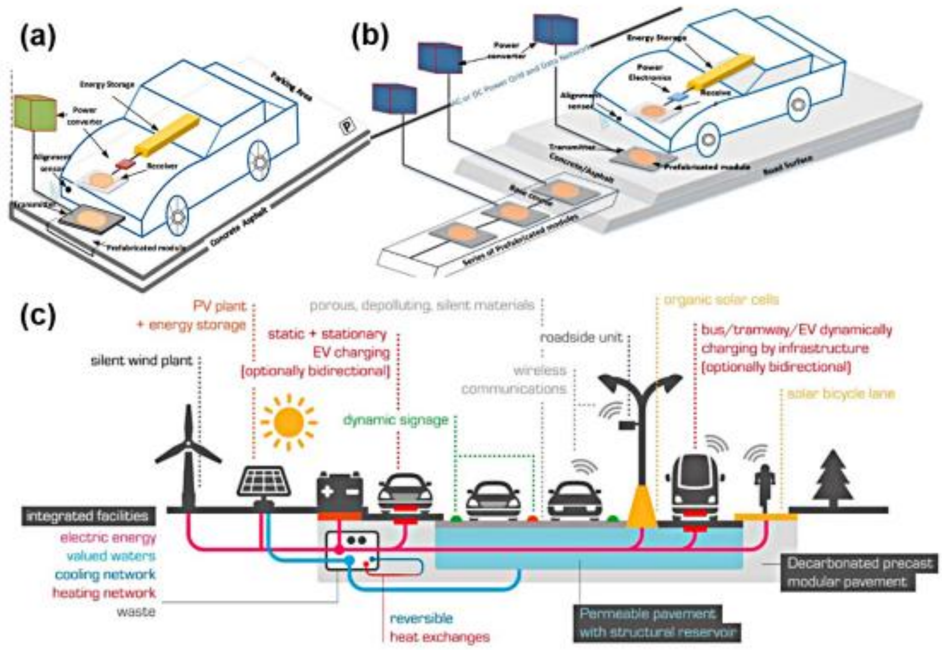
1.Wireless charging

Wireless Charging and autonomous driving make the use of EVs more convenient and intelligent, and can also significantly increase the range of EVs without increasing the weight of the battery.



- **"Plugless Power"** is a set of EVSE series products of Evatran, which consists of a wall-mounted control board for parameter setting, a floor-mounted parking mat with a transmitting coil, and a vehicle adapter with a receiving coil mounted on the vehicle chassis . When an EV with a Plugless power adapter is parked on the parking mat, the control system will automatically

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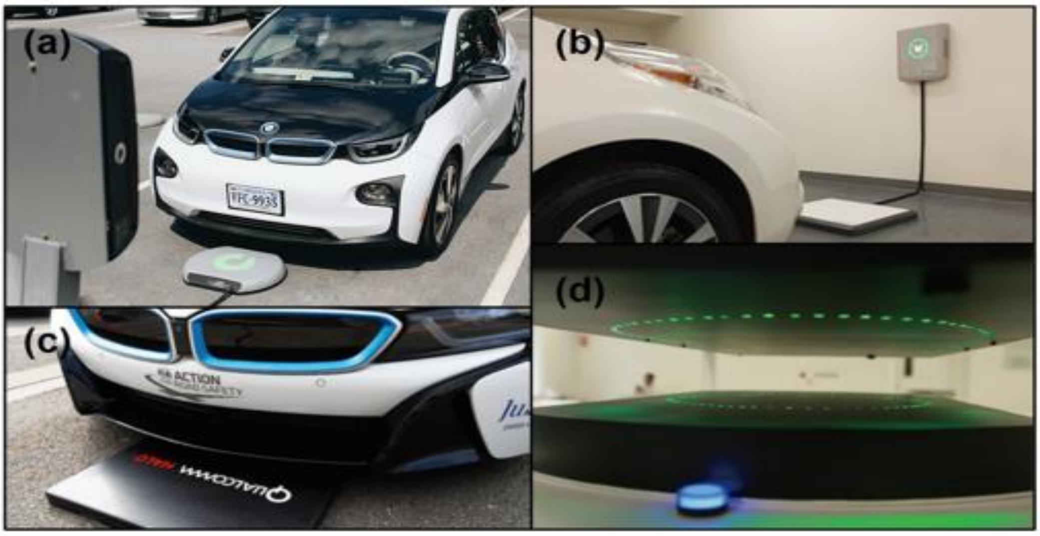
detect and align the position of the transmitting and receiving coils and perform a sustained charge, up to 7.2 kW of power, without any external physical connection.



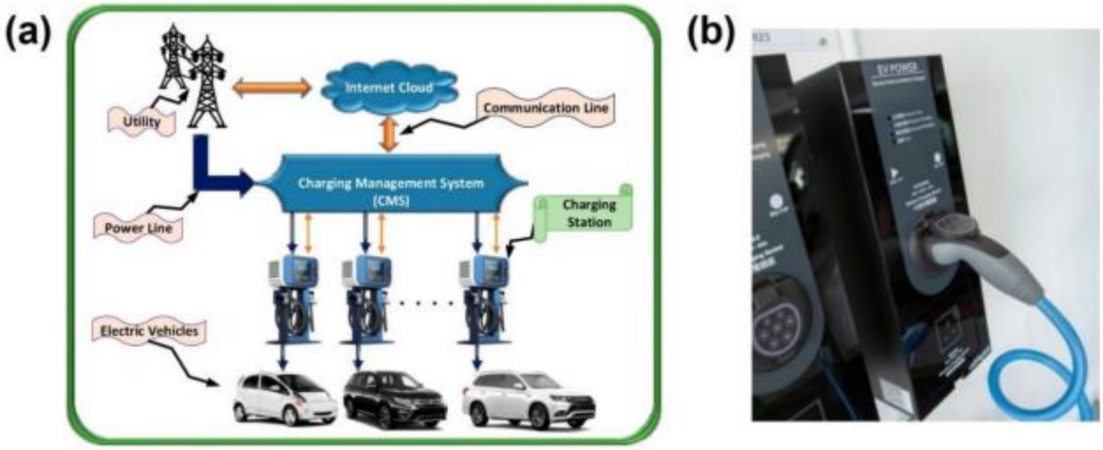
- **WiTricity,** an American high-tech company, has produced a wireless energy transfer system based on alternating magnetic resonance .The system (Figure b) has an adjustable output power interval, with a wide range from 3.6 to 11 kW, so that it can satisfy the charging needs of PHEVs equipped with small and short-range battery packs to EVs equipped with large ones.
- Qualcomm Halo™ wireless charging products, introduced by Qualcomm, are high-power wireless charging solutions based on magnetic resonance technology (Figure c). The system covers 3.7 kW, 7.4 kW, 11 kW, and 22 kW of wireless fast charging power using a charging mat mounted on the ground with over 90% system efficiency . Moreover, it is also equipped with auxiliary functions such as foreign object detection (FOD) and positioning guidance. Qualcomm sponsored the Formula Electric Championship as a founding technical partner and integrated the 7.4 kW system into the BMW i8 medical vehicle.
- Zonecharge demonstrated its wireless charging technology based on magnetically coupled resonance for the first time in 2016. The solution includes a wireless charging product for EVs, with a power of 6.6 kW, and another for buses, with a power of 30 kW.
- In 2017, based on the Society of Automotive Engineers (SAE) standard, the Automotive Platforms and Application Systems (APAS) R&D Centre and Hong Kong Productivity Council (HKPC) developed a wireless charging device based on magnetic resonance coupling that can fill up a small EV in 3 h with a power output of 7 kW, as shown in Figure d.

The Dynamic EV Charging (DEVC) concept, which charges moving vehicles on the road, has attracted the research attention of innovators, scientists, and engineers, as the developing trend for the next generation of wireless charging. Qualcomm, an industry leader and in-depth researcher in wireless charging, has taken the lead in conducting actual track tests about DEVC

Electric buses and trucks require large-capacity battery packs due to their long-distance travel and heavy-duty feature. The increasing usage of EVs has dramatically expanded the demand for high-power fast charging. The substantial government subsidies for the construction of shared charging infrastructure also make it possible to promote fast wireless charging up to 50 kW.

2.Smart Power Distribution Technologies

Effective power distribution can charge more EVs without major infrastructure upgrades. Instead of installing additional physical electrical capacity, the power distribution system can dynamically share existing power across more EV chargers to charge more EVs.The advantages of smart power distribution are demonstrated by a representative system in Figure a.



- The introduction of renewable energy sources and secondary batteries in the electricity grid is emerging as an advanced technology of smart power distribution that facilitates the implementation of fast EV chargers. The secondary batteries and renewable energy sources, such as green energy generators, can refeed surplus power generation into the electricity grid to boost its power capacity. Secondary batteries, as energy buffers, can supply energy in emergencies when the grid is overloaded or disconnected.
- The development of EV power distribution technology faces abundant opportunities with challenges. The growing number of EVs will place unprecedented demands on the urban grid's peak carrying capacity, as most EV charging times are highly overlapping, typically at night. Concentrated charging results in an extreme spike in electricity demand during those hours each day, whereas power capacity is not fully utilized for most of the rest .This situation can adversely affect everyone who receives electricity service. On the one hand, the voltage drop and instability caused by the concentration may result in the breakdown of appliances. On the other hand, the

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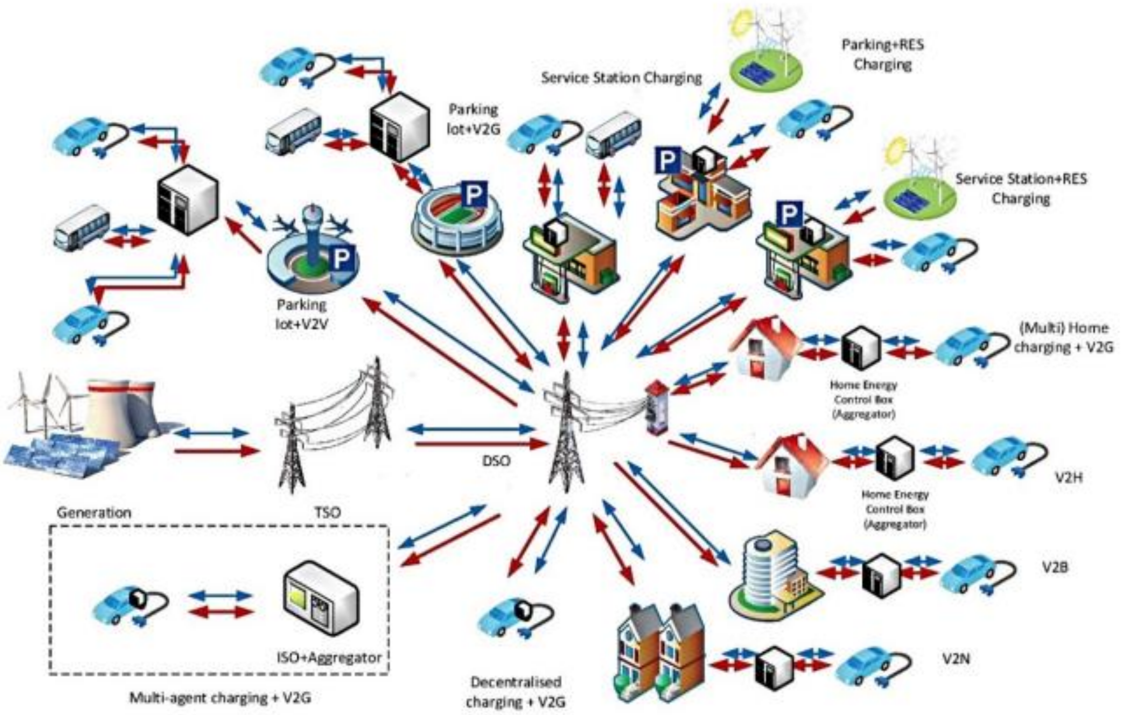
- increase in generation capacity and the reinforcement of hardware facilities inevitably raise the electricity price.

V2H and V2G Technologies

The V2H system allows the use of electricity already stored in the EV to power the household, whereas the V2G system supports selling the electricity already stored in the EVs to the grid and purchasing electricity from the grid, charging the EV . The V2H and V2G systems mainly consist of battery management software, hardware that supports bidirectional electricity transmission, and communication modules between the vehicle terminal and the grid operator . Intelligent algorithms monitor the operating status of the grid in real-time to determine whether a vehicle can purchase electricity from or sell electricity to the grid at the moment and whether a vehicle is available to reach the corresponding agreement.



As demonstrated in Figure , with the V2H system, owners could charge their EVs during the day via solar energy or during non-peak times with lower electricity prices, and then power household appliances at night or during peak hours using the stored energy . The onboard battery can also provide emergency power in case of grid breakdown. Using the V2G system, owners could charge during non-peak hours and feed the stored energy back to the grid to boost its electricity capacity during peak hours . This charging strategy could relieve grid loading pressure during peak hours and stabilize grid operation by reducing the range of loading fluctuations. Meanwhile, EVs can serve as sizeable offline storage devices for renewable energy, facilitating the dispatch of electricity across time scales.

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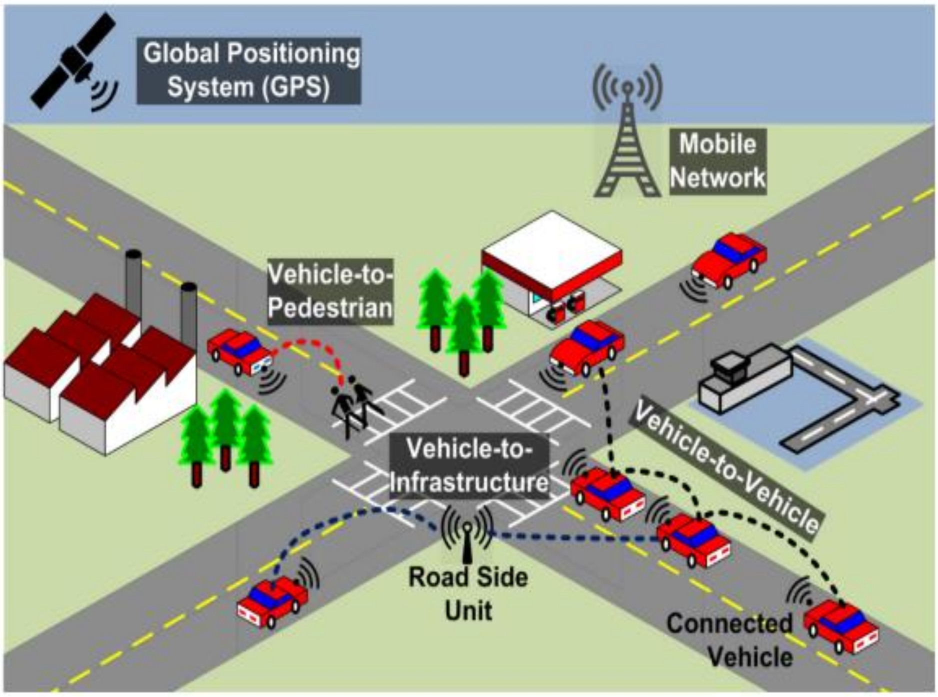
3.Connected Vehicles

- Integrated with three networks: intra-vehicle network, inter-vehicle network, and onboard mobile Internet, the CV, also known as the "Internet of Vehicles" (IoV), is intrinsically a large distributed communication system for V2X interaction, where X involves other CVs, individuals, and networks.
- As a profound scenario for the application of the Internet of Things (IoT) in the intelligent transportation system (ITS), the CVs enable a multifunctional network that supports intelligent transportation management, intelligent dynamical information services, and intelligent driving control .
- The information exchange process follows specific communication protocol standards such as the IEEE 802.11p WAVE standard or cellular data protocols [84]. Typical CV systems are equipped with interfaces to WiFi or cellular networks (GSM, HSDPA, LTE, or 5G expected to be fitted on a large scale) and other short-range communication technologies.
- When the vehicle is connected to the network, it has access to numerous cloud information services, such as instant emergency calls, real-time navigation, and media amusement, as exhibited in Figure 7. As the communication gateway, the global vehicular ID (GID) terminal is undoubtedly the technological key of the CV .
- With integrated information sensors, the network communication module, and global online identification (an "online vehicle plate"), it allows the vehicle to have worldwide network connectivity and global positioning and tracking capabilities .



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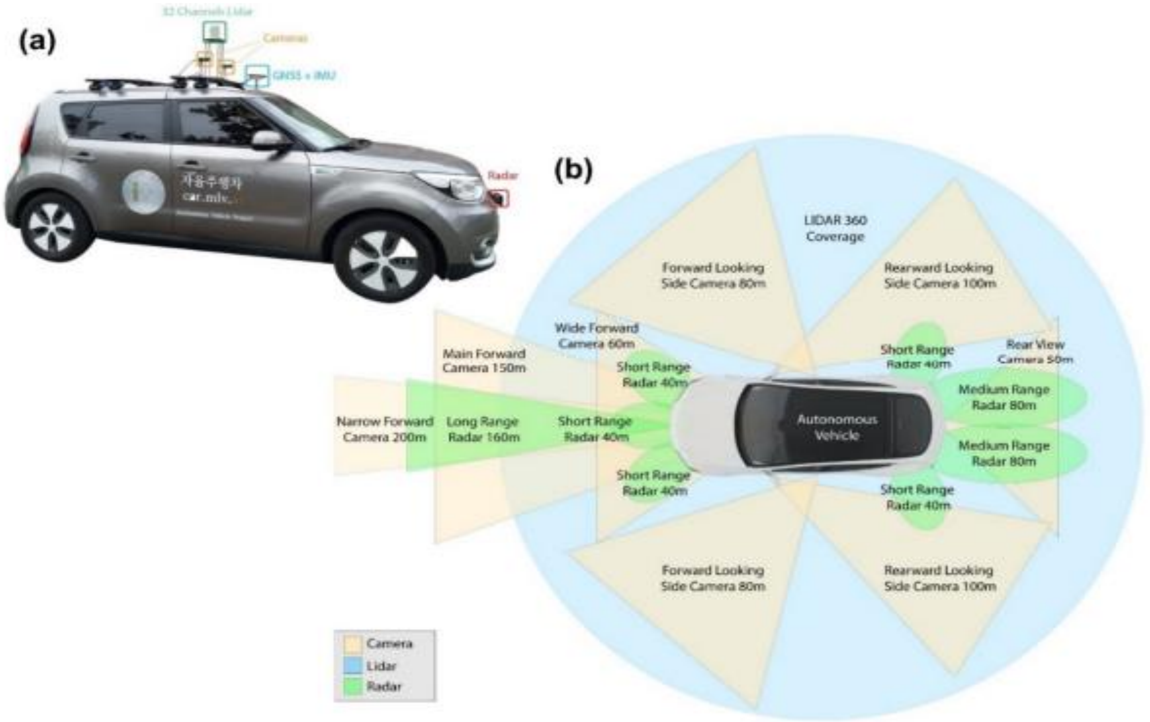
4. Autonomous Driving

- Advanced sensory technology is one of the most critical factors in realizing autonomous driving. In order to popularize autonomous driving, the vehicle itself is required to enhance the manoeuvrability of a human driver. The combination of different sensors can enable the vehicle to outperform humans in terms of visionary perception of the environment. The installation positions, coverage and maximum range of typical sensors for environment perception in an autonomous vehicle are displayed in Figure.



The existing sensory technologies for automated driving can be principally divided into six categories:

- Ultrasonic sensors Sensing range: 0–2 m.
- Computer vision Sensing range: 0–120 m.
- Radio detection and ranging (radar) sensors Sensing range: 0–250 m.
- Light detection and ranging (LIDAR) sensors Sensing range: 0–200 m.
- Odometry
- GPS and cloud technology.

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- Control Technology

Intelligent control systems infer proper path planning according to road signs, obstacles, and the behavior of other traffic participants, based on understanding large amounts of sensor data. Although the technical means differ, most autonomous vehicles maintain a local map of surroundings in real-time, then use algorithms to identify appropriate paths and send corresponding commands to end-effectors for lateral and longitudinal vehicle control.

- Telematics Technology

Telematics is compounded by the terms "telecommunications" and "informatics". Generally, Telematics is every application of telecommunications that integrates information exchange and services technology. As a technology covering everything about GPS and navigation systems, it can send, receive, and store information related to remote items— such as vehicles—through telecommunication devices . Telematics systems help insurance companies predict traffic dangers based on recorded human driving behavior and readily identify valid and independent safety features.

Comparison of EVs and IC Engine vehicles

An electric vehicle (EV) is a type of vehicle that runs on electricity from batteries, while an internal combustion engine (ICE) vehicle is a vehicle that runs on gasoline or diesel fuel.

Here is a comparison of electric vehicles (EVs) and internal combustion engine (ICE) vehicles:

1) Power source: EVs run on electricity stored in batteries, while ICE vehicles run on gasoline or diesel fuel.
2) Emissions: EVs produce far fewer emissions compared to ICE vehicles, as they do not rely on gasoline or diesel to power the vehicle. The primary source of emissions from EVs is the generation of electricity used to recharge the batteries.
3) Performance: EVs have instant torque, which allows for quick and smooth acceleration, while ICE vehicles rely on gears to increase their power. EVs are also typically quieter and require less maintenance, as they have fewer moving parts.
4) Refueling: EVs can be charged at home or at charging stations, while ICE vehicles require regular trips to the gas station to refill the fuel tank. Charging an EV can take anywhere from 30 minutes to 12 hours, depending on the charging speed and battery size.
5) Cost: The upfront cost of EVs is typically higher than that of ICE vehicles, but the cost of ownership can be lower due to lower fuel and maintenance costs.
6) Driving range: The driving range of an EV is limited by the size of its battery, while the driving range of an ICE vehicle is limited by the amount of fuel in its tank.
7) Infrastructure: There is a growing network of charging stations for EVs, but they are not yet as widespread as gas stations.
8) Environmental impact: EVs have a lower environmental impact than ICE vehicles, as they produce fewer emissions and do not rely on finite fossil fuels.

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Both EVs and ICE vehicles have their own advantages and disadvantages. The choice between the two will depend on individual needs and priorities, such as driving range, cost, and environmental impact.

Electric Vehicle Component &Architecture

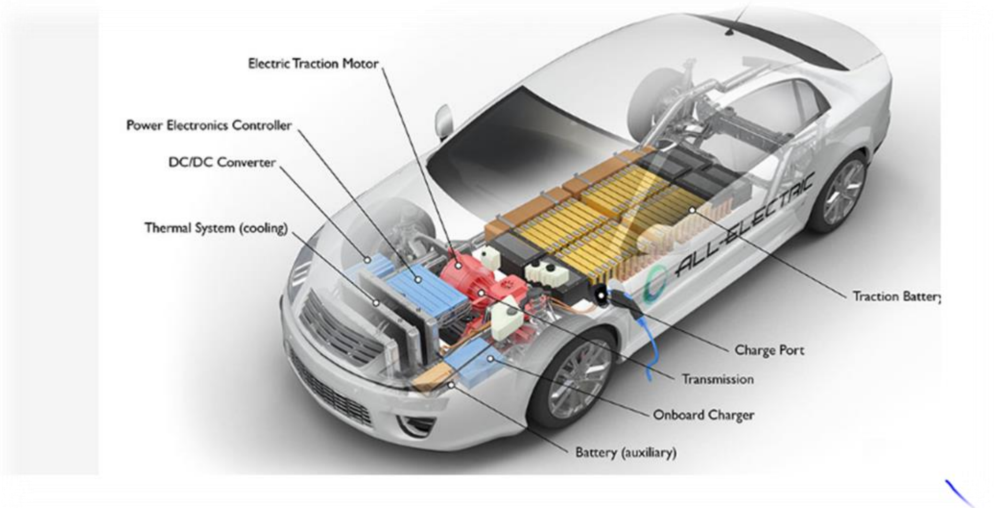
When designing the architecture for EV it is mandatory to use modeling and simulation tools, with specific consideration of electric power train, including battery, power electronics, electric motors, sensors, and control system.

In ICE engine power production is not uniform because reciprocating components causes mechanical loss hence engine is not self-started to resolve this issue other components are added in the architecture that resulting in the engine becoming heavy as the other hand in Electric vehicle architecture consists of a motor which is self-started and can easily control by the input current. They produce uniform power and speed at the output because of this reason motor is lighter than ICE.

The Electric vehicle architecture is the backbone of the EVs. Electric vehicle architecture is categorized in the following way Following are the Types of Electric Vehicle:

- Hybrid electric vehicle
- Plug-in hybrid electric vehicle (PHEV)
- Battery electric vehicle (BEV)

The Electric vehicle architecture consists of 5 important components and through this component; the power train is completed in EV, such as the Electric motor, Battery pack, and Inverter, Charger, DC-DC converter, etc.



1. **Battery:** The battery is the most important component of an EV, as it stores and supplies the electrical energy needed to power the vehicle. The battery can be made up of lithium-ion or other types of cells, and its size and capacity determine the driving range of the vehicle.
2. **Electric motor:** The electric motor is responsible for converting the electrical energy stored in the battery into mechanical energy, which drives the wheels of the vehicle.

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3. **Power electronics:** The power electronics are responsible for managing the flow of electricity between the battery and the electric motor. They act as a bridge between the battery and the motor, controlling the speed and torque of the vehicle.
4. **Charger:** The charger is responsible for recharging the battery of the vehicle. There are two types of chargers: onboard chargers, which are built into the vehicle, and external chargers, which are separate devices.
5. **Drivetrain:** The drivetrain is the system that transmits the power from the motor to the wheels of the vehicle. In an EV, the drivetrain is usually simpler than in an internal combustion engine (ICE) vehicle, as it does not have gears, a transmission, or a differential.
6. **Control systems:** The control systems are responsible for managing the various components of the vehicle, such as the battery, the electric motor, and the power electronics. They work together to ensure the vehicle operates efficiently and safely.

The architecture of an EV can be divided into two main components: the high-voltage system, which includes the battery, the electric motor, and the power electronics, and the low-voltage system, which includes the control systems, the charging system, and the drivetrain. These two systems are separated by a high-voltage isolation barrier to ensure safety and prevent electrical hazards.

Autonomy and vehicle computing needs

The increasing trend towards autonomous vehicles is driving the need for advanced vehicle computing systems. In autonomous vehicles, the computing system plays a critical role in ensuring the vehicle's safety and reliability. Here are some of the key computing needs for autonomous vehicles:

1. **Sensors**: Autonomous vehicles use a variety of sensors, such as cameras, lidar, radar, and ultrasonic sensors, to gather data about their surroundings. The computing system must process and analyze this data in real-time to make informed driving decisions.
2. **Computer vision:** The computing system must have the ability to perform computer vision, which is the process of analyzing and interpreting visual information from cameras and other sensors. This is crucial for tasks such as object detection, tracking, and classification.
3. **Machine learning:** Machine learning algorithms are used to train the autonomous vehicle's decision-making systems, allowing the vehicle to learn from experience and improve its driving skills over time.
4. **Real-time computing:** Autonomous vehicles require real-time computing capabilities, as the computing system must respond quickly to changes in the vehicle's surroundings. This requires high-performance processors and low latency networks.
5. **Connectivity:** Autonomous vehicles must have reliable and high-speed connectivity to the internet and other vehicles, as well as the ability to communicate with other vehicles and infrastructure, such as traffic lights and road signs.
6. **Safety:** Safety is a top priority in autonomous vehicles, and the computing system must be designed to meet strict safety standards and certifications. This includes redundant systems

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and fail-safe mechanisms to ensure the vehicle can continue to operate safely even if a component fails.

7. **Data management:** Autonomous vehicles generate vast amounts of data from their sensors and systems, and this data must be managed and processed efficiently. The computing system must be able to store and access this data quickly and reliably, as well as ensure that sensitive data is protected and secure.
8. **Power management:** Autonomous vehicles must be able to operate for long periods of time without recharging, which requires efficient power management. The computing system must be designed to minimize power consumption while still providing the performance required for autonomous driving.
9. **Robustness:** The computing system in an autonomous vehicle must be robust and reliable, as even minor failures can have serious consequences. This requires the use of high-quality components and strict testing and validation processes.
10. **Human-machine interface:** In autonomous vehicles, the computing system must provide a user-friendly interface for passengers and operators. This may include touchscreens, voice control, and other input methods, as well as visual displays to provide information about the vehicle's state and surroundings.
11. **Cost-effectiveness:** While autonomous vehicles require advanced computing systems, these systems must also be cost-effective, as this will play a key role in determining the commercial viability of autonomous vehicles. This requires a careful balance between performance and cost, as well as the use of mass-production techniques to reduce costs.
12. **Scalability:** As the number of autonomous vehicles on the road increases, the computing systems must be scalable and able to accommodate the growing demand for computing resources. This requires the use of flexible and modular systems that can be easily upgraded and expanded as needed.

The computing needs for autonomous vehicles are complex and demanding, requiring advanced technologies such as computer vision, machine learning, real-time computing, connectivity, and safety. These requirements are driving innovation in the field of vehicle computing and shaping the future of autonomous transportation.

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