The Role of Electrification of Transport in The Energy Transition

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Abstract

Electric vehicles (EVs) have undergone tremendous advancement as a result of battery technology advancement and reduction in the cost of batteries. Few years ago, electric vehicles were much expensive compared to the conventional vehicles. The current development is redesign of the infrastructure and further advances in battery technology in terms of charging and charge storage and cost reduction. The transport sector is a leading contributor to greenhouse gas emissions and measures have to be put in place to reduce these emissions. Measures being undertaken in the energy sector include development of alternative electric and/or hydrogen powertrains and replacement of the hydrocarbon fuels and internal combustion engine (ICE) designs. To realise large scale penetration of electric vehicles (EV), there is need for adequate charging infrastructure. Road transport is a large emitter of greenhouse gas (GHG) emissions and therefore electric mobility provides huge potential to reduce global greenhouse gas emissions. The various V2X technologies are V2G, G2V, V2H, V2V. These technologies enable the electric cars to play a grid role not just as power consumers, but as decentralised power sources as well. The vehicle to grid (V2G) and grid to vehicle (G2V) technology be used to have EVs may clustered via aggregator to offer grid power services like load leveling, voltage regulation, and peak shaving, at a lower cost and with less environmental impact. Therefore, smart grid technology deployment will enhance the operation and control of electric vehicles making them important energy transition facility

Key Words: Energy transition, electric cars; electrification of transport; energy transition

1.Introduction

Road and rail transport is the a principle mode of transport for people and cargo most of which are driven by fossil fuel powered internal combustion engineers(Oladunni et al. 2022). The use of electric vehicles can reduce greenhouse gas emissions, reduce dependency on fossil fuel sources, promote deployment of renewable energy sources, the dependency on fossil fuel and mitigate the release of ozone depleting substances. Other than provision of motive force for transport applications, the development of new concept of Vehicle-to-Grid creates an import opportunity for vehicle owners to supply power to the grid and generate some revenue and a key pathway for the energy transition (Goel et al. 2021). Passenger transportation accounts for 50 to 60% of energy consumed by the transport sector with private cars being the dominant mode of passenger transport (Rodrigue 2022). The freight transport accounts for 40 to 50% of transport sector energy consumption. For most economies globally, the road transport accounts for 80% of domestic energy consumption. Rail and maritime shipping, are more energy-efficient modes with greater marginal energy consumption levels. Domestic waterways provide energy-efficient means of transport for both cargoes and passengers (Rodrigue 2022). The transport sector activities account for between 25 and 30% of all greenhouse gas emissions globally (Rodrigue 2022).

After some period of low sales, 2020 saw a boom in sales for electric vehicles. Germany realised a 263%, growth, France, 202% and the UK 140% rise in sales of plug-in electric passenger cars. The US and China which have largest EV market realised smaller growth of 4% for U.S. and 15% for China. China is the world leader in sale of plug-in electric vehicles (PEVs), but Europe dominate plug-in car sales in 2020 with Norway, Iceland, and Sweden leading at 74.8%, 28 45%, and 32.3% shares, respectively(Agarwala & Das 2021; Li & Loo 2014). The global stock of electric cars hit the 10 million mark, or 43% increase over the previous year in the year 2020. Electric vehicles accounted for two thirds of new electric car registrations in 2020 with China having the largest fleet of h four and a half million electric cars in 2020. However, Europe had the largest annual increase, with electric vehicles stock hitting 3.2 million(Knobloch, 2022). This is a significant growth compared to data for 2012, which showed that the global EV stock was 180,000, or 0.02 % of total passenger cars. The projection is that the share will reach over 2 % by 2023(Li & Loo 2014).

Application of electricity in transport include use of plug-in hybrid EVs (PHEVs), battery EVs (BEVs), and fuel-cell EVs (FCEVs). The PHEVs use both diesel/gasoline and electricity and. Challenges facing electrical transport include the threat to grid stability from simultaneously charging of thousands of EVs. Technological advances that support electric vehicles include battery technologies like nickel-metal hydride (Ni-MH) and lithium-ion (Li-Ion), intelligent energy management systems, and vehicle-to-grid (V2G) technology. Compared with plug-in EVs, FCEVs generate electricity by refilling with fuels like hydrogen, alcohols or ethers instead of battery recharging [15, 16]. The performance of FCEVs is limited by storage system technology e.g. how to store hydrogen in the vehicle, and related high cost of energy storage and fuel cells limits commercial deployment(Li & Loo 2014), (Skouras et al. 2022).

The transport sector is a leading contributor to greenhouse gas emissions and measures have to be put in place to reduce these emissions(Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju 2022e; Kabeyi & Oludolapo 2020a). Measures being undertaken in the energy sector include development of alternative electric and/or hydrogen powertrains and replacement of the hydrocarbon fuels and internal combustion engine (ICE) designs.(Dodds & McDowall 2014). Among the greatest challenges facing humanity today is to tackle the effects of effects of climate change, by reducing the global carbon dioxide (CO_2) emissions so as to maintain the global average temperature between 1.5 and 2ºC above pre-industrial concentration levels(Costa et al. 2021). Energy consumption and related carbon emissions pose a serious challenge to the transport sector with about 40% increase in global energy consumption by the sector between 2008 and 2017 with road transport accounting for more than 90% of these consumption (Costa 2020). About 30% of the global population lived in urban centres in 1950, and about 54 % in 2014(Evaldo Costa et al. 2017). Projections show that about 66% of global population will reside in urban centres by the year 2050. The transport sector accounts for about 25% of global carbon dioxide (CO_2) emissions while the road sector accounted for about 75% of the transport emissions in the years 2014(Evaldo Costa et al. 2017). Electrification of transport would reduce the ecological footprint, minimise anthropogenic emissions, and contribute towards greenhouse gas emissions mitigation(Evaldo Costa et al. 2017). The European Union has a target to reduce GHG emissions by the transport by 20% by the year 2030, and reduce further by 70% by the years 2050 with respect to the years 2008 emission levels(Evaldo Costa et al. 2017). In the search for low-emission by nations, transport a sector that has significant reduction potential and should therefore be a priority in realisation of Paris agreement targets(Costa et al. 2021).

The use of ethanol as a transportation fuel is one of the leading measures and policy options to limit emissions in the transport sector(Evaldo Costa et al. 2017).. Ethanol as an engine fuel has less greenhouse gas emissions, when compared with fossil fuels like petrol and diesel(Kabeyi 2020; Kabeyi 2022; Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju 2021b). However, ethanol production must increase and its application in transport will have to compete with several other industrial and domestic applications of ethanol to meet the expected increase in demand for energy applications(Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2022; M. J. B. K. Kabeyi & O. A. Olanrewaju 2022). The market for Electric vehicles (EVs) is growing globally and this promise to provide a viable pathway in the energy transition. Studies by (Evaldo Costa et al. 2017) on the interplay between ethanol and EV, using LEAP energy model considering emission coefficients from life cycle analysis for Brazil, showed that electric vehicles provide a higher positive impact on climate change mitigation compared to ethanol.

Introduction of electric and hybrid passenger cars, and use of ethanol as a fuel, will help cities the effort to mitigate the greenhouse gas (GHG) emissions by reducing the consumption of fossil fuels. Studies show that from EV are significantly less that ethanol if the wheel to wheel (WTW) approach for CO_2 emissions estimation(Evaldo Costa et al. 2017).

The transport sector which provides mobility for freight and people is a significant energy consumer accounting about 25% of global energy consumption (Rodrigue 2022). The transport sector accounts for more 50% of the petroleum oil used and about 25% of global energy related (CO_2) emissions. Based on the year 2005 baseline, the transport energy consumption and related CO_2 emissions are expected to grow by more than 50% by the year 2030 and more than double by the year 2050. The fastest growth is expected from light-duty vehicles which comprise of the passenger cars, sport utility vehicles, small vans, and vehicles. Growth is also expected in air travel and road freight(Anable et al. 2012). The transport sector is considered as the most difficult and expensive to reduce emissions and energy demand based on outcomes of forecasting and modelling frameworks that analyse the technical solutions and economically optimal and rational behaviour of individual consumers and markets, based on consumer preferences. The diffusion of advanced vehicle technologies is considered as core means to decarbonise the transport sector with many promising technologies being at development level and not yet commercially mature. These technologies include electrification of the passenger vehicle fleets (Anable et al., 2012).

Many transport sector low carbon transitions are based on decarbonisation in terms of technological transformation, but we have opportunities for behavioural or demand side orientated measures(Dodds & McDowall 2014). The transport sector has an important role to play in economic development especially by facilitating choices among consumers like where to live, where to work, how and where to spend your leisure hours(Machado et al. 2021). The transport sector also offers employment to millions of people globally. The combined passenger and freight transport accounts for about 20% of the global greenhouse gas emissions(Dodds & McDowall 2014)

There are many technologies for the transport sector, but use of diesel and petrol still dominates the transport sector (Machado et al. 2021). Other options include natural gas, biogas and bio methane, fuel cells with studies showing that use of biogas and fuel cell hydrogen trucks can significantly reduce greenhouse gas emissions and therefore when it comes to economic viability, the use of natural gas and hybrid trucks seem to offer best substitutes to diesel and petrol (Machado et al. 2021).

Passenger cars account for emissions of around five gigatons of CO_2 per year which is similar to the entire CO_2 emissions of the US which currently is worlds second, largest polluter. While household heating is responsible for about two and a half gigatons of CO_2 emissions per year, that is similar to the entire CO2 emissions of India, which is the third largest polluter globally (Kabeyi & Olanrewaju, 2020; Machado et al. 2021).

The internal combustion engine which is the traditional prime mover for the transport sector a conversion efficiency of about 12.7%. Pure electric vehicles on the other hand have a conversion efficiency of about 51.6%. Fuel cell vehicles (FCVs) have efficiency of 28.3% and hydrogen ICE (HICE) vehicles have 26.6% conversion efficiency(Zhang et al., 2017). It is projected that will account for about 10% of overall electricity consumption by 2050 due to expected electrification of using electric vehicles (EV) and plug-in hybrid electric vehicles (PHEV). With electrification, if vehicle charging is not intelligently managed intelligently managed, the effect will be increase peak loading on the electricity infrastructure which will call for major infrastructure investment to avoid supply failure. The solution is to use smart grid technology to facilitated strategic charging when demand is low to utilise low-cost generation and extra system capacity, or charging when renewable electricity contributor to the power mix is high. The smart grid technology will also facilitate supply of electricity from electric vehicles from power stored in the vehicle batteries when electricity demand is high (International Energy Agency 2011; Smale et al. 2017).

Projections show that with increase of electric and hybrid vehicles, the transport sector will consume close to 10% of electricity. Charging of many electric vehicles needs meticulous monitoring to avoid a surge of peak loading on the electricity infrastructure. Smart grid technology can facilitate prioritization of charging in cases of low demand exploiting the use of both low cost generation and extra system capacity. Smart grids synchronize across the value chain from end users to investors and shareholder by significantly reducing the associated costs that come with environmental impacts and enable high system performances(Kanyowa & Mahoso 2021).

2.Energy and Emissions in Transport Sector

Electrification of transport is a potential panacea to many countries facing vehicular pollution. However, we could have a scenario where emissions may rise if electric vehicles depend upon energy generated from non-renewable sources like coal. Several studies have shown the electric vehicles would indirectly emit more CO_2, NO_X, and SO_2 if power is from coal although CO emissions are likely reduce compared to conventional vehicles(Nimesh et al. 2022).

Energy supply and transport are the most greenhouse gas emitting sectors although the emissions in the energy supply sector have been reducing as more electricity and heat production comes from renewable sources. As a contract, the emissions in the transport sector, rose between 2013 to 2017 in regions like the European Union. Therefore, the transport sector requires radical and rapid changes to realise the emissions and targets as outlined in the Paris Agreement as well as the European green deal. Transport electrification is an option as an emission reduction strategy if electricity generation is dominated by renewables, nuclear or cleaner fossil fuels. The use of smart electric vehicle charging can balance variable power generation from renewable sources, potentially allowing higher penetration of renewables. Results from models show that integration of renewables, energy storage and electric vehicles in grid management improves the reliability of the grid and reduces energy costs(Moses Jeremiah Barasa Kabeyi & O A Olanrewaju 2022). As a result of sectoral interrelations, it is advisable to jointly analyse the transport and power sectors in long-term development (Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2022; Neniškis et al. 2021). Reduction of air pollution is an important action in support of sustainable development, but global concern of anthropogenic emission mainly targets GHG which are subject to global agreements and taxation, while, air pollutants is generally governed by local legislation and policy (Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju 2022e; Machado et al. 2021).

New alternative fuels are often associated with sustainable development, efficiency, energy savings, and environmental conservation. A life cycle assessment is recommended whenever new vehicle technologies are developed, for vehicle and the complete fuel cycle from production to fuel use. LCAs are often considered the proper way to compare energy and environmental performance fuels or energy supply(Kabeyi 2018; Machado et al. 2021).

2.1 Energy options for Transport Sector

The various energy and technology options for the transport sector are biofuels, natural gas and biomethane, hydrogen, hybrid technology and electrical traction.

Biofuels

Biofuels are renewable sources like ethanol, methanol, and biodiesel produced by fermentation biomass like sugar cane, corn, cereals called first-generation biofuels or biomass like wood and grasses called second-generation biofuels(Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2022b, 2022c, 2022d). The main challenge of biofuels is that they compete with food applications like sugar production, etc.

Natural gas and Biomethane

Natural gas is abundant in supply and is a more efficient and environmentally sustainable fuel among fossil fuels. namely in its compressed form. Natural gas is also the cleanest fossil fuel with wide range of applications in other sectors of the economic and can be easily substituted with biomethane which enriched biogas, a renewable energy resource(Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2022a, 2022g). Natural gas has been used as a transportation fuel since the early 20th century, but only marginally the late 20th century. Natural gas is preferred for large fleets of vehicles with extensive travel like public transit buses or delivery trucks. Natural gas accounted for about 4% of transport fuel in 2015 with the share expected to double by the year 2025(M. kabeyi & O. Olanrewaju, 2022; Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2021b; Kabeyi & Oludolapo 2020b).

Hydrogen

Use of hydrogen as a transportation fuel first to produce hydrogen by electrolysis of water or extracting it from hydrocarbons among others then storing hydrogen on-board in liquid form then use a fuel cell to generate electricity to propel the vehicle. Hydrogen fuel cells are more energy-efficient compared to gasoline and generate near-zero pollutants(Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju 2022g). The problem is that hydrogen production is energy intensive process and requires electricity. Hydrogen requires low temperature/high-pressure storage tanks which increases weight and volume to the vehicle. Hydrogen may be ideal for ship and aircraft propulsion too(Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2022a).

Electricity

A pure electric vehicle is considered to be a more efficient alternative to an engine propelled vehicle. All electric cars are generally easier and cheaper to manufacture similar sized fuel-cell vehicles. The main limitation for electric cars is lack of storage systems that can provide driving mileage similar to those of conventional vehicles making the electric car less competitive than internal combustion powered vehicles. The range for commercially available electric vehicles is 550 kilometers as in 2022, although the range is increasing making them unsuitable for long-distance travel since recharging takes between 8 hours for a full charge and 30 minutes for a fast 80% charge compared to standard vehicles which take 5 to 10 minutes to fill the gasoline tank(Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju 2022; Moses Jeremiah Barasa Kabeyi & O A Olanrewaju 2022).

Hybrid vehicles

These vehicles consist of a propulsion system using an internal combustion engine supplemented by an electric motor and batteries to combine the efficiency of electricity with the benefit of long driving range of an internal combustion engine. The primary source of energy and power is conventional fuels and the engine which also charge the battery via a generator for alternative propulsion. The engine automatically starts when the battery is discharged without a driver's intervention. Braking energy can also be used to power the generator to recharge the battery.

2.2. Maintenance and Safety of Electric Vehicles

The plug in and hybrid electric vehicle (PHEVs) and hybrid electric vehicle (HEVs) have same general maintenance requirements as the conventional vehicles, except that the maintenance requirements are lower due to limited number of moving parts and fluids to change (US Department of Energy, 2020).
Since the PHEVs and HEVs still have internal combustion engines, their maintenance needs are still similar to conventional cars. The electrical system which consist of the battery, electric motor, and associated electronics need minimal scheduled maintenance, while the braking systems are longer lasting than conventional vehicles due to regenerative braking. Electric vehicles have less maintenance requirements due to the following reasons; Regular maintenance needs for battery, motor, and associated electronics are low, less fluids are used with no engine oil, which require regular maintenance, regenerative braking significantly reduces brake wear, and the electric car has fewer moving parts or rotating parts compared to the conventional fuel engine(US Department of Energy 2020).

Battery Maintenance

Batteries used in electric vehicles have a limited charging cycles. Safe operating temperature is maintained by use liquid coolant in some batteries. Batteries require regular checks as may be instructed by the manufacturer. The electric car batteries are generally designed to last as long as the expected lifetime of the vehicle., but would eventually wear out. Many manufacturers offer 8-year/100,000-mile warranties for the batteries. The batteries are expensive but the prices have been dropping significantly over time (US Department of Energy 2020).

Safety Requirements

All-electric vehicles, PHEVs, and HEVs have high-voltage electrical systems I the range of 100 to 600 volts. The batteries are encased in sealed shells and should meet testing standards like extreme temperature, overcharge, short circuit, vibration, humidity, collision, fire, and water immersion. The vehicles and accessories have insulated high-voltage lines and safety features with ability to deactivate the electrical system whenever a collision or short circuit is detected. Since all-electric vehicles tend to have a lower center of gravity compared to the conventional ones, they tend to be more stable and less likely to roll over(US Department of Energy, 2020).

Emergency Response and Training

Electric-drive vehicles have cutoff switches to isolate the battery and disable the electric system, and all high-voltage power lines in case of an emergency while they are clearly designated in characteristic colors for caution. Manufacturers generally deal with emergency response preparedness through training and publishing emergency response guidelines. (US Department of Energy 2020).

2.3 Transport and Environment

Transportation delivers substantial socioeconomic benefits while at the same time, impacting environmental systems. Transport activities support growing mobility demands for passengers and freight, but are also associated with environmental impacts with some serious negative impacts. Environmental conditions also affect transport systems in terms operating conditions and infrastructure requirements like construction and maintenance. Therefore, transport and the environment are perceived as a system with retroactive effects.

All modes of transport and the transport sector account for close to for about 22% of global CO_2 emissions in addition to environmental impacts noise and pollution. The growth of freight and passenger mobility have further enhanced the level of emissions from the transport sector. The total emissions from the transport is a function of the **emission factor** of each transport mode and the **level of activity**(Rodrigue, 2022). The transport systems which include transport infrastructures, vehicle operations, have negative environmental effects like noise, greenhouse gas emissions, particulate emissions and other pollutants to environment (Rodrigue, 2022).The private cars are the most dominant source of transport but it has poor conversion efficiency with only 12 to 30% of the fuel energy being used to provide momentum, depending on engine type used (Rodrigue 2022).

The environmental impacts of transport are related to transport modes, energy supply systems, emissions and infrastructures over which they are deployed. Vehicles emit pollutants like carbon dioxide, nitrogen oxide, and noise, and physical damage of the transport infrastructures. Many environmental impacts of transport systems are externalized, and hence few realise the benefits of mobility but the whole society assumes the costs. Transport sector sustainability is a core issue in the provision of mobility, particularly decarbonisation(Rodrigue, 2022)

The iincrease in passenger and freight mobility has expanded the role of transportation as a producer of emission of pollutants. The impacts fall within three categories:

Direct impacts.
These are immediate environmental consequences of transport activities with clear cause and effect relationship e.g. noise, vibration, carbon monoxide emissions, smoke, etc.

Indirect impacts.
These are secondary or tertiary effects to the environment by the transport activities and often have a higher consequence than direct impacts. However, the involved relationships are often misunderstood and more difficult to establish e.g. the particulates which are associated with incomplete combustion in internal combustion engine cause respiratory and cardiovascular complications (US Department of Energy, 2020).

2.4 Cumulative impacts
Cumulative environmental impacts of the transport sector are additive, multiplicative or synergetic consequences. They are varied effects of direct and indirect impacts to the environment ecosystem, that are often unpredictable like the climate change which have complex causes and consequences that combine the impact of natural and anthropogenic factors which transport as just one of the players or contributors (Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2021a; US Department of Energy, 2020).
The total cost of transportation activities which includes environmental damage, are not generally fully assumed by the service providers and users. Many environmental management challenges arise from failure to consider real costs of transportation. In reality, many costs are involved, ranging operations, compliance, and external i.e. assumed by the society. The external costs account excess of 30% of the estimated automobile ownership and operating costs. Therefore, without considering the significant environmental costs, of the car usage, the transport sector is considered to be subsidized, and costs accumulate as environmental pollution(Moses Jeremiah B. Kabeyi & O. A. Olanrewaju, 2021; US Department of Energy 2020).

V2X TECHNOLOGIES
V2X technologies refers to various technologies associated with grid connected vehicles like the Vehicle to Grid (V2G), vehicle to house (V2H), and vehicle to vehicle (V2V) technologies. V2X stands for vehicle-to-everything and includes arrangements like vehicle-to-home (V2H), vehicle-to-building (V2B) and vehicle-to-grid services. This is based on the application of electricity from vehicle batteries which can be powering homes, buildings or the electricity grid(Moses Jeremiah Barasa Kabeyi & O A Olanrewaju 2022; Rodrigue 2022).

2.5 Vehicle to Grid (V2G) and Grid to Vehicle (G2V)
Vehicle-to-grid, or V2G, technology is a smart charging technology enable cars to supply power to the grid. The technology treats high-capacity batteries as prime mover for electric vehicles as well as a backup storage cells for the power grid. The electric vehicle-to-grid technology is also called car-to-grid in an arrangement where a car battery can be charged and discharged based on the active signal to incur electricity production or consumption(Moses Jeremiah Barasa Kabeyi & O A Olanrewaju, 2022). The idea behind vehicle-to-grid is the same as regular smart charging also called V1G charging, that facilitate control the charging of electric cars to adjust the charging power to be to increase or decrease depending on ned and circumstances. Vehicle-to-grid enables the charging power to momentarily pushed back to the grid from electric cars batteries to balance variations in energy production and consumption(Rodrigue 2022)..

The vehicle-to-grid helps mitigate climate change by allowing the power system to balance more and more renewable energy by deployment of renewable energy sources, and introducing advanced energy storing energy. The electric vehicle batteries remain the most cost-efficient energy storage because they require no additional investments in hardware. V2X turns EV charging from electrical demand response to a battery solution. In V2G arrangement, electric vehicles are linked to the electricity grid to facilitate grid charging and discharge of batteries. In this case, the electric vehicles are referred to as grid-connected EVs (GEVs) (Bhattarai et al. 2022; Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju 2022).These vehicles have a plug-in feature equipped with a bidirectional charger enabling the battery to draw energy from the grid to the battery and back. Other potential products and services related to V2G concept depending upon the discharging and charging ability of the GEVs and grid efficient and energy needs are vehicle-to-home (V2H), vehicle-to vehicle (V2V). These technologies will enable the vehicle to act as a variable load and source of distributed electricity for the grid. Extensive research is done and is still ongoing to optimize the performance and cost of the V2X technology to make it technically and economically viable(Bhattarai et al. 2022; Moses Jeremiah Barasa Kabeyi & O A Olanrewaju 2022).

By means of V2G technology, parked electric vehicles are used as distributed sources of electricity with ability to store, and release energy at the time of need which allows power exchange between the electricity network and the Electric vehicle. The result is increased electricity generation capacity for the gird which improves stability, reliability, and efficiency the power system. The AC–DC Bidirectional electronic converters, namely (BADC) and DC–DC (BDC), are used to enable G2V and V2G interchange (Parazdeh et al., 2022). Converters facilitate high efficiency power conversion, and with progress in converter technology, EV charging stations assist in the transition to a green environment (Parazdeh et al. 2022).

The V2G technology be used to have EVs may clustered via aggregator to offer grid power services like load leveling, voltage regulation, and peak shaving, at a lower cost and with less environmental impact. Therefore smart grid technology deployment will enhance the operation and control of electric vehicles making them important energy transition facility(Bhattarai et al., 2022; Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2022e, 2022f).

Vehicle to House (V2H)

In many electricity markets, peak demand occurs between 5 p.m. and 11 p.m. for most grids which is often a time when most private and public vehicles are parked at homes or stations. During this period, the vehicle to house (V2H) technology facilitates connection of parked vehicles to an electricity distribution board of home to meet demand peak demand. During off peak hours, the same vehicle can be changed later from vehicle to grid or vehicle to house to grid to vehicle connection to have the batteries charged preferable by power from intermittent sources like rooftop solar PV(Parazdeh et al., 2022).

Vehicle to Vehicle (V2V) Technologies

The V2V or 'Vehicle-to-Vehicle' technology facilitate interchange between vehicles. Other than vehicles exchanging power or charging, sensors can also be applied to provide to the car with data and information from other cars a few hundred meters ahead or even hidden cars. The normal or traditional V2V is performed through an energy aggregator like in electrical power grid, made of a combination of the vehicle-to-grid (V2G) and grid-to-vehicle (G2V) operation modes. The normal V2V power transfer is based on four power conversions because each on-board electric vehicle battery charger has two power converters (de-de and dc-ac). In advanced form V2V power transfer, can take place in ac and dc, focusing in the V2V power transfer using dc power (dcV2V). Modern V2V can discard an aggregator connection by directly connecting the EVs, charging one EV from the other which can reduce the four power conversions to a single one, hence higher overall efficiency in power transfer between electric vehicles (Li et al., 2022; Sousa et al., 2018). To realise the V2V charging mechanism, requires properly management of different expectations of EVs and reach the win-win situation for electric vehicles and the grid. (Li et al. 2022).

3. Role of Transport Sector in Energy Transition

The electric vehicles have potential to reshape the transport sector by reducing carbon emission and contribute to the realisation of the global climate targets. The life cycle emissions of electric cars is half or less than half of the emissions of comparable gasoline-powered vehicles(Glandorf, 2020). The electric vehicles (EVs) also emit carbon emissions through the manufacturing process and electricity generation process used to recharge. The average conversion efficiency of EVs is 77% of electrical energy from the grid to power at the wheels, compared to gasoline vehicles which generally convert between 12 to 30% of the energy in gasoline to power at the wheels(Glandorf, 2020; Moses Jeremiah Barasa Kabeyi & Oludolapo Akanni Olanrewaju, 2022; Moses Jeremiah Barasa Kabeyi & O A Olanrewaju, 2022).

3.1 Challenges of Electric Vehicles

The main threat or obstacle in the electrification of transport is competition from traditional means of transport like fossil fuels, ethanol, gas and others that are well established in several countries [14]. Therefore, the consumers compare the performance of electric cars against the conventional engine driven cars. Notable challenges include;

Charging times

Electric vehicles have three major levels of chargers available for use in charging. They are the standard 120-volt plug, mainly used for home appliances that charges slowly but can charge the battery to near full capacity over several nights or about 20 to 40 hours. The second type is the 240-volt "level two" chargers which can service 20 to 25 miles of charge in an hour, hence shorten time by eight hours or less. These chargers can use the same outlet required for clothes dryers or electric ovens. For EV industry, connecters for level two charging are known as SAE J1772. The level 3 direct current (DC) fast chargers can fill the battery to about 80 percent in 30 minutes. There are important cost differences between charger types(Moses Jeremiah Barasa Kabeyi & O A Olanrewaju, 2022). Costs for level two charger's components vary from $2,500 to $7,210 while a DC fast charger vary from $20,000 to $35,800. (Glandorf 2020).

Charger compatibility

Level two charger development is a relatively coordinated process, where all automakers except Tesla use a common charge port model. Tesla drivers on the other hand use an adapter to connect. Three types of DC fast chargers used by auto manufacturers. They are the SAE Combined Charging System (CCS), CHAdeMO, used by Mitsubishi and Nissan the Tesla Supercharger used by Tesla drivers. Lack of vehicle compatibility from universal vehicle access to gas stations could be an obstacle to widespread adoption of electric vehicles (Glandorf 2020).

3.2 Availability of charging infrastructure

Electric vehicles must be charged at electrical outlets in order to run hence many EV owners charge their cars at home using special wall-mounted chargers. Most electric vehicles can travel between 150 and 250 miles on a charge, based on model. However, drivers who live in apartments may have parking that are not equipped with charging infrastructure which is an inconvenient(Glandorf, 2020). There is need for expanded charging infrastructure for EVs making long-distance trips that require multiple stops for charging. For longer trips, many EV owners experience range anxiety with fear that the car will run out of power away from a suitable charging station. Concerns about range and charging availability limit on consumer uptake of electric vehicles (Glandorf 2020; Moses Jeremiah Barasa Kabeyi & O A Olanrewaju 2022).

3.3 Grid capacity

Electrification of transport implies that millions of people will rely on the electric grid in new ways which means that power generation capacity should increase to accommodate these millions of vehicles without straining the grid. The US Department of Energy foresees a 38 percent increase in electricity consumption by 2050 mainly due to largescale uptake of electric vehicles. The grid ability to handle electric vehicles charging depends the time of charging the vehicles with lower chance of grid overload if it is done during off-peak hours (Glandorf, 2020; Moses Jeremiah Barasa Kabeyi & O A Olanrewaju 2022).

3.4 Vehicle costs

Electric cars use expensive materials and parts for making batteries making them generally more expensive than their fuel powered vehicles. With new electric vehicle costing around $30-40,000 although the prices have a falling trend over time (Glandorf 2020).

3.5 Charging behaviour

The charging behaviour of electric cars differs significantly from the engine driven with about 80 percent of EV charging being done at home. Many electric vehicle car owners are uneasy about the prospect of long charging times at public stations on long distance travel (Glandorf 2020).

3.6 Sales outlook.

In as much as the stock of electric vehicles market is growing, there is need for dramatic increase to meet the emissions and climate targets. In 2019 for example, electric cars made up 2.1 percent of all new light-duty vehicle sales in the US up from 0.7 percent in 2015. The main players in the market are Tesla with largest share of new electric vehicles in the US but the Nissan Leaf has the largest share of used EV sales. It is predicted that electric vehicles will account for about 7% of all vehicles on the road by 2030, or about 18.7 million vehicles in the US. (Glandorf 2020).

3.7 Charging station financing and ownership

Charging stations are expensive to install with, public station component costing generally from about $2,500 for a level two charger to $35,800 for a DC fast charger and these exclude installation costs and other costs like pursuing permitting process, regulations, and interconnection with utilities hence the legitimate question on who pays for the construction of these stations. Charging station construction is currently paid for by car and energy companies and business owners, parking lots and garages, shopping centres, and retailers seeking to attract EV users (Glandorf 2020).

3.8 Pricing
EV charging applies different pricing schemes unlike the conventional ones where fuel pricing is common. This can lead to inconsistent pricing and at times high charging costs. Home charging prices are expressed in kilowatt-hour (kWh) and are set by utility companies. Public charging stations charge per-session fees, per-minute, and tiered pricing based on a vehicle's max charging speed. The inconsistency and lack of transparency limit the adoption of electric vehicles due to frustration and negative customer experiences. Many states allow per-kWh pricing, and in some cases with a tiered pricing structure, charging higher rates for faster charging speeds. (Glandorf 2020).

3.9 Legislation
Legislation is one of the factors limiting electric vehicle e.g. employees benefits in some states or countries only recognise fuel not electric vehicle charging which limits wide spread use of EVs. In the US, the Electric Vehicle Freedom Act, or EV Freedom Act (H.R. 5770), intends to construct electric vehicle supply equipment along all public roads in the National Highway for EV drivers to travel anywhere on these roads in the continental United States, Alaska, Hawaii, and Puerto Rico without running out of charge.

4. Results and Discussion
The electrification of road transport features prominently policy frameworks of many countries as a strategy to reduce greenhouse gas emissions. The main challenge is that fossil fuels continue to dominate the electricity generation mix pausing a challenge to the role of electric cars in effectively reducing overall emissions hence the need to rapidly decarbonize the grid electricity mix. Studies however indicate that the current carbon intensities of electricity generation are less emission intensive than the electric cars and heat pumps in many global economies which account for close to 95% of the global transport and heating demand. Therefore even if future end-use electrification is not matched by rapid power-sector decarburization, electrification of road transport will still reduce global greenhouse gas emissions(Knobloch et al. 2020).

The transportation sector is among the rapidly growing energy intensive sectors globally making it a leading contributor to global greenhouse gas emissions. Electrifying the transport promise to be a sustainable solution to reduce emissions.(Bhattarai et al., 2022).Studies have shown that on average across the globe, electric vehicles account for 31% of emissions savings per kilometer, while heat pumps can save 35% in emissions per unit heating unit heating. Even where the grid is not quite clean, electrification of transport presents substantial emissions savings for most countries while huge savings are realized if effort to decarbonize the grid is made(Knobloch et al. 2020).

4.1 Behavior and Transport Sector Emissions
There is significant evidence that behaviour change has a key role to play in decarbonising the transport sector. Demand-side measures can reduce kilometres travelled or, shift to less carbon intensive modes of transport. Scenario that rely on shifts in human activity patterns, preferences and price signals have far reaching implications other aspects of the economy and society e.g. wider consumption practices like leisure, food consumption and work practices, preferences for residential and business location and knock-on land values (Glandorf 2020).

Energy/Technology Options for the transport Sector
The basic energy sources and technologies used by vehicles are biofuels, natural gas and biomethane, hydrogen, electricity and hybrid technology. These systems are analysed in table 1 below.

Table 1. Energy systems and technologies for vehicle

		Description	Remarks
1	Biofuels	Biofuels are renewable sources like ethanol, methanol, and biodiesel produced by fermentation biomass like sugar cane, corn, cereals called first-generation biofuels or biomass like wood and grasses called second-generation biofuel	The main challenge of biofuels is that they compete with food applications like sugar production, etc.
2	Natural gas and Biomethane	Natural gas has been used as a transportation fuel since the early 20th century, but only marginally the late 20th century. Natural gas is preferred for large fleets of vehicles	Natural gas is the cleanest fossil fuel and is easily substituted by renewable biomethane

		with extensive travel like public transit buses or delivery trucks.	
3	Hydrogen	Requires first to produce hydrogen by electrolysis of water or extracting it from hydrocarbons among others then storing hydrogen on-board in liquid form then use a fuel cell to generate electricity to propel the vehicle.	Hydrogen production is energy intensive and expensive. Storage challenges due to pressure and expensive materials
4	Electricity	A pure electric vehicle is considered to be a more efficient alternative to an engine propelled vehicle. All electric cars are generally easier and cheaper to manufacture similar sized fuel-cell vehicles	Limited by energy storage capacity and service distance
5	Hybrid	These vehicles consist of a propulsion system using an internal combustion engine supplemented by an electric motor and batteries	Combine the efficiency of electricity with the benefit of long driving range of an internal combustion engine but expensive

From table 1, it is noted that various energy systems and technologies are available with different strengths and opportunities. The application and objectives will influence the best choice as the global shift to net zero emissions take shape. Electric vehicles compete against conventional engines and energy systems., both renewable (biofuels, biomethane and hydrogen based on source) and non-renewable i.e. diesel, petrol and natural gas.

4.2 Performance of Transports Drive Options

The various drive systems for vehicle are internal combustion engines, pure electric drives, fuel cells and hydrogen internal combustion engines. Table 2 below shows the conversion efficiencies of internal combustion engines, pure electric vehicles, fuel cell vehicles and hydrogen internal combustion engines.

Table 2. Efficiency of vehicle energy conversion systems

	Option	Conversion efficiency(%)	Rank
1	Internal combustion engine	12.7	4
2	Pure electric vehicles	51.6	1
3	Fuel cell vehicles (FCVs)	28.3	2
4	Hydrogen ICE (HICE) vehicles	26.6	3

From table 2, it is noted that electric vehicles have the highest conversion efficiency, followed by fuel cell, hydrogen and internal combustion engines in reducing efficiencies. Therefore, the internal combustion engine has the lowest conversion efficiency compared to other available drive systems.

4.3 V2X Options

There are several V2X technologies available for electric cars. They include Vehicle to grid (V2G), grid to vehicle(G2V), vehicle to house) V2H) and vehicle to vehicle (V2V).

Table 3. V2X systems

	Technology	Description	Application
1	V2G and G2V	Vehicle-to-grid, or V2G, technology is a smart charging technology enable cars to supply power to the grid These vehicles have a plug-in feature equipped with a bidirectional charger enabling the battery to draw energy from the grid to the battery and back. The role can be reversed depending on need	In V2G technology, parked electric vehicles are used as distributed sources of electricity with ability to store, and release energy at the time of need
3	V2H	The vehicle to house (V2H) technology facilitates connection of parked vehicles to an electricity distribution board of home to meet demand peak demand. During off peak hours, the same vehicle can be changed later from vehicle to grid or vehicle to house to grid	The technology can be used to supply power when the grid power is expensive or is not available. The system can also utilize intermittent sources like rooftop solar PV and wind for later use

4	V2V	The normal V2V power transfer is based on four power conversions because each on-board electric vehicle battery charger has two power converters (de-de and dc-ac). In advanced form V2V power transfer, can take place in ac and dc, focusing in the V2V power transfer using dc power (dcV2V).	Modern V2V can discard an aggregator connection by directly connecting the EVs, charging one EV from the other at higher efficiency

From table 3, it is observed that the V2X technologies are V2G, G2V, V2H, V2V. These technologies enable the electric cars to play a grid role not just as power consumers, but as decentralised power sources as well. The electric vehicle can therefore be used to stabilise the grid and be a source of grid power to the power grid.

5. Challenges/Limitations of electric Vehicles

Many factors limit the rapid deployment of electric vehicle globally and should be addressed for faster adoption of the electric transport. These limitations are summarised in table 4 below.

Table 4. Limitations of electric cars

	Limitations	Remarks and recommendations
1	Charging time	Electric vehicles have three major levels of chargers available for use in charging with charging time ranging from few days for 120-volt plug chargers to 30 minutes by the level 3 direct current (DC) fast chargers
2	Charger compatibility	They are the SAE Combined Charging System (CCS), CHAdeMO, used by Mitsubishi and Nissan the Tesla Supercharger used by Tesla drivers. Lack of vehicle compatibility from universal vehicle access to gas stations could be an obstacle to widespread adoption of electric vehicles
3	Charging infrastructure	There is need for expanded charging infrastructure for EVs making long-distance trips that require multiple stops for charging. Concerns about range and charging availability limit on consumer uptake of electric vehicles
4	Grid capacity	Electrification of transport implies that millions of people will rely on the electric grid to charge their cars hence the risk of grid overload
5	Vehicle costs	Electric cars use expensive materials and parts for making batteries making them generally more expensive than their fuel powered vehicles.
6	Charging behaviour	About 80 percent of EV charging being done at home unlike the conventional engine cars which fuel in gas stations
7	Sales outlook	The stock of electric vehicles market is growing, but the market share remains low hence need to increase to meet the emissions and climate targets.
8	Charging station financing and ownership	Charging stations are expensive which raises the legitimate question of who pays for the public charging stations
9	Pricing	EV charging applies different pricing schemes leading to inconsistent pricing and at times high charging costs
10	Legislation	Legislation is one of the factors limiting electric vehicle hence the need to develop a legislative and policy framework to encourage use of electric cars

From table 4, it is noted that electric vehicles still encounter numerous shortcomings compared to the conventional engine driven cars. They include lack of supporting legislation, low sales volumes, lack of standardization like charger incompatibility, inadequate grid capacity to handle the many electric vehicles and concerns over ownership and financing of public charging infrastructure.

6. Conclusion

The electric vehicles have potential to reshape the transport sector by reducing carbon emission and contribute to the realisation of the global climate targets. The life cycle emissions of electric cars are half or less than half of the emissions of comparable gasoline-powered vehicles. The electric vehicles market is widespread with vehicles ranging from electric bikes to airplanes. Electric powered passenger cars have received the widest attention and hold and important position in the energy transition. The main drivers of the electric vehicle markets are government incentives, environmental awareness and concerns, high fuel prices, phasing off govern subsidies for fossil fuels. The main challenges facing the electric vehicle industry are limited range and slow charging times, high cost of EVs, and inadequacy of infrastructure to support the electric vehicles industry. Nevertheless, the EV industry is growing significantly across the globe, across the globe particularly with advancement in battery technologies particular the all-solid-state batteries with reduced charging time, increasing range, and reduced manufacturing costs. Although the hybrid, Plug in Hybrid and Electric Vehicles are expensive compared to the traditional vehicles, they have increasing fuel economy. V2X technologies are V2G, G2V, V2H, V2V. These technologies enable the electric cars to play a grid role not just as power consumers, but as decentralised power sources as well. The electric vehicle can therefore be used to stabilise the grid and be a source of grid power to the power grid. The concept of Vehicle-to-Grid (V2G) and Grid –to-Vehicle (G2V) can be used to either deliver power to the grid or use the grid to charge the battery in the absence of non-conventional. V2G is an important aspect of energy security, renewable energy, and hence an important tool against the global warming issues. Projections show that with increase of electric and hybrid vehicles, the transport sector will consume close to 10% of electricity. Charging of many electric vehicles needs meticulous monitoring to avoid a surge of peak loading on the electricity infrastructure. Smart grid technology can facilitate prioritization of charging in cases of low demand exploiting the use of both low cost generation and extra system capacity

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