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APPRAISNG THE PROSPECTS AND SCENARIO OF LOW CARBON ENERGY TRANSITION FOR ROAD TRANSPORT SECTOR IN MAIDUGURI METROPOLIS

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ABSTRACT

Climate change mitigation requires a transition to clean and sustainable transport system. This paper evaluates the potentials for the adoption of low carbon vehicles (LCVs) in the road transport sector in Nigeria, with Maiduguri Metropolis as the case study. Five regular LCV options were chosen, namely; Biofuel, Battery Electric, Compressed Natural Gas (CNG), Liquefied Petroleum Gas (LPG) and Hydrogen fuel cell (HFC) vehicles. Primary data were collected through interviews with various relevant actors (government, industry, markets, etc.) in the road transport sector. The questions were structured in such a way that different possible economic conditions of LCVs existed in terms of cost, in relation to the conventional ICE Fossil Fuel Vehicles (FFVs). The LCVs' operating costs were indexed against gasoline FFV, using different cost combinations. The result shows that the lower the initial purchase costs of LCVs in relation to the FFVs, the higher the tendency for their adoption and vice versa. With the right policy in place, the likely LCV alternative to emerge is either CNG or LPG vehicles through a de-alignment/re-alignment scenario.

Keywords: Climate change; GHG Emissions; Low carbon vehicles; Transition pathways; Transport fuels.

1.0 INTRODUCTION

1.1 Background of the Study

Greenhouse gas concentrations (mainly CO_2) in the atmosphere have risen significantly since the beginning of the industrial revolution in the mid-eighteenth century. The combustion of fossil fuels releases carbon dioxide (CO_2), a major greenhouse gas (GHG) into the atmosphere. There is strong evidence that the emissions of GHGs (mainly CO_2, CH4, NOx, O3 and Synthetic chemicals) are the primary cause of climate change and global warming that has occurred in recent decades. Due to human activities, CO_2 concentration in the atmosphere has risen to about 43% since the beginning of the industrial revolution in the mid-eighteenth century – half of that figure (about 21.5%) was emitted since 1980 (IPCC, 2019; IEA, 2012).

Anthropogenic activities such as burning fossil fuels like coal, oil and natural gas, as well as deforestation contribute significantly to the increase in CO_2 concentration in atmosphere. Eighty seven percent (87%) of human produced carbon emissions that come from the combustion of fossil fuels. The remainder results from the clearing of forests and other land use changes (9%), as well as some industrial processes such as cement manufacturing (4%). Therefore, global warming is significantly attributable to fossil fuel consumption in various sectors such as power generation, industry, transport, domestic and agriculture (Le Quéré *et al.*, 2012).

The three major sectors that use fossil fuels are Electricity, transportation and industry; producing about two-thirds of global carbon dioxide emission in 2021 (US Environmental Protection Agency, 2023). According to International Energy Agency, the transport sector accounts for around 23-28% of global emissions (IEA, 2020; Statista, 2023; US Environmental Protection Agency, 2023). The share of road transport subsector is about 80% of total transport emissions (Statista, 2023). Meanwhile the transport sector in Nigeria contributes about 32% of the country's total CO_2 emissions, but the sector accounts for 44% of energy-related emissions (Worldometer, 2023). The road transport subsector is responsible for around 95% of total transport sector emissions in Nigeria (DCC, 2018). Hence, the road transport is a major contributor of GHG emissions, both at the global and national levels, and thus, a low carbon transition in the road transport sector (particularly through fuel switch) would provide significant environmental, social and economic benefits. However, there are opportunities as well as barriers to the adoption of low emission vehicles in the Nigerian road transport sector. Socio-technical transition pathways are Transformation, Reconfiguration, Substitution and De-alignment/Re-alignment pathways (Geels, 2005, 2011; Geels and Schot, 2007).

1.2 Nigeria's response to GHG emissions

Nigeria has been actively engaged in international climate policy negotiations since it became a Party to the United Nations Framework Convention on Climate Change (UNFCCC) in 1994 and ratifying its Kyoto Protocol in 2004. Since then, the Nigerian Government has enacted polices, plans and regulations that seek to encourage the drive towards sustainable energy, such as the 2009 Draft Renewable Electricity Policy, Renewable Energy Master Plan 2012, the National Climate Change Policy and Response Strategy (NCCPRS) 2012, the National Energy Policy 2013 and the Draft National Energy Master Plan (NEMP) 2014, among others.

The National Climate Change Act 2021 of Nigeria was signed into law on the 18th of November 2021. The Act was considered to be a right step in the right direction, especially in making Nigeria live up to expectation in actualizing its commitment to Paris Agreement, Nationally Determined Contributions (NDCs), Kyoto Protocol, the United Nations Framework Convention on Climate Change (UNFCCC), UN Sustainable Development Goals and other standards and guidelines relevant to climate change adaptation and mitigation (KPMG, 2022).

A recent demonstration of Nigeria's commitment to climate action was the launch of the Nigeria Energy Transition Plan (ETP), a strategy developed for achieving net-zero emissions, ending energy poverty, and driving economic growth. The Nigeria ETP sets out a timeline and framework for the attainment of emissions' reduction across five (5) key sectors; Power, Cooking, Oil and Gas, Transport and Industry for the achievement of carbon neutrality by 2060 in terms of the nation's energy consumption. Within the scope of the ETP, about 65% of Nigeria's emissions are affected. The ETP requires significant emission reductions in the transportation sector, targeting around 97% due to uptake of EVs in passenger car segment (FGN, 2022).

The aim of this study is to analyze the prospects and potential transition pathway(s) in Nigeria's road transport sector and the likely low carbon vehicles (LCVs) option(s) that will emerge in the new regime. The objective is to use both primary and secondary, numerical and descriptive data to assess the potentials for large-scale adoption of low carbon vehicles (LCVs) in Nigeria's road transport sector. Data sources included government MDAs, industries, markets, academic institutions, road vehicle users, civil society (households), and organizations.

The scope of the study was limited to road transport regime and LCVs included are Biofuel Vehicles (ethanol and biodiesel), Compressed Natural Gas Vehicles (CNGVs), Liquefied Petroleum Gas Vehicles (LPGVs), Battery Electric Vehicles (BEVs), and Hydrogen Fuel Cell Vehicles (HFCVs). The comparison of the LCV options considers their technical, economic and environmental factors (in relation to gasoline vehicles), with the research data placing more emphasis on their operating costs rather than their initial purchase cost or overall levelized costs.

2.0 LITERATURE REVIEW

Nitte and Salahudeen (2023) underscored the role of policies for adopting low-carbon technologies and system integration in Nigeria's energy transition. Although the nation has abundant energy resources, a sizeable section of its people lacks access to power, creating severe problems with energy accessibility. To address this problem, the government has implemented several programmes and plans. However, the high initial costs of low-carbon technology, particularly in rural regions, have hampered their development. The study emphasises the importance of a user-centred approach, contextualisation of technology, consideration of social norms, and the role of intermediaries in facilitating the adoption and use of low-carbon technologies. It also highlights how policy interventions can either accelerate or delay the adoption of low carbon technologies. The study recommends that policymakers and technology developers adopt a holistic approach by considering various issues in policy formulation concerning the transition to low-carbon technologies.

Hussaini *et al.*, (2022) offered a descriptive analysis of the Motorcycle-Tricycle transition process that occurred in the commercial road transport sector in Maiduguri city, the capital of Borno state, Nigeria. The transition dynamics involved was analysed using socio-technical transition pathway theory (the multi-level perspective) and a wide range of data on historical population of commercial passenger transport vehicles in the road sector in Maiduguri, collected from field survey study. It was found that the motorcycle-tricycle transition pathway involved a complete de-alignment of the regime in the absence of a significant re-alignment dynamics.

Akujor *et al.*, (2022) reviewed the various sub-sectors of the Nigerian transport sector with their corresponding energy consumption rates, and indicated that it is dominated by fossil fuel regime, with consequent contributions to carbon emissions. They gave some recommendations for gradual decarbonisation of the sector, including revitalisation of the rail and water transport; encouragement of mass transit; improving the state of security on Nigerian roads; employment of low-carbon fuels (biodiesels); and use of electric vehicles.

Sa'ad *et al.,* (2022) examined the prospects and challenges of transition to efficient and environmentally friendly road transportation system in Nigeria. The study used time-series data from 1981 to 2019 within the framework of demand for gasoline and diesel in the structural time-series estimation model, where the concept of the asymmetric price increase and underlying energy demand trends were incorporated into the models. The findings of the study showed that both gasoline and diesel are highly price inelastic, and suggests that governments should combine incentives and public enlightenment on the importance of energy efficiency as well as transport infrastructure improvements with gradual adjustments of domestic prices in the short run. However, in the long run, policy should be extended towards massive investments in the transformation and modernization of the whole transportation sector in line with sustainability, efficiency and environmentally friendly goals in the transportation system of the country.

Dioha and Kumar (2020) used a bottom-up optimisation model to explore the energy system implications of five alternative policy pathways for the Nigerian transport sector. The study considered fuel switching, improved fuel economy, modal shifting, improved logistics, and carbon tax for the period 2010–2050. The results show that the alternative pathways will reduce energy demand and CO_2 emissions significantly. Additionally, low-carbon pathways will enhance air quality, energy security, and the productive use of energy.

Abam *et al.*, (2021) conducted a study on the environmental sustainability of the Nigeria transport sector (NTPS) through the decomposition and decoupling analysis from 1988–2019. The objective of the study was is to determine ways of saving energy in the NTPS and reduce carbon emission for a sustainable environment. Based on the Logarithmic Mean Divisa Index (LMDI) and the Tapio approach, built on Kaya extended identity, five decoupling indicators (economic activity, energy structure, economic structure, population and energy intensity) were considered based on the four energy carriers consumed in the NTPS. The results identified three decoupling states; weak negative decoupling, weak decoupling and strong decoupling. The energy intensity, economic activity, population and energy structure prevented decoupling during the study period, while the economic structure factor promoted decoupling. The overall impact of carbon emissions from NTPS was estimated at 44.45 $mtCO_2$. The study suggests frameworks that will support policy makers to formulate broad base policies for environmental sustainability.

Osunmuyiwa *et al.*, (2018) analysed renewable energy transitions in Africa, using Nigeria as a case study, to elucidate the analytical and methodological challenges that sustainability transition studies are facing in developing countries, particularly rentier states. They employed the instrumentality of the multi-level perspective (MLP) on socio-technical transitions theory. Based on a detailed analysis of Nigeria, they argued that better accounts for the rentier character of the state including the role of political elites and prevalent client-patron relationships. As such, the study makes an important contribution to the further refinement and enrichment of the MLP by focusing on the political dimensions of energy transitions. Welle and Kustar (2022) reiterate that Africa's cities are facing several challenges in which transport is one of many important issues. Stakeholders are faced with addressing and prioritizing challenges with a limited set of resources and capacity.

Chukwu *et al.*, (2015) conducted a study on energy demand and consumption in Nigeria's transportation sector. The transportation fuel use in Nigerian, usually in the form of liquid fuels (petrol and diesel), increased over the period from 2005 to 2009. The paper discusses among other things, the transport modes and their energy consumption pattern looking at the implications of the trend in energy utilization to the national energy consumption. It also looks at the share of the transport sector energy consumption in the country and recommended possible ways of improving it.

Aba *et al.*, (2023) aimed at analysing the energy, economic and environmental implications of adopting alternative transition fuels and powertrains for transport in the Nigerian context in a subsidy and subsidy-exempt regime. The fuel options included compressed natural gas (CNG) and electricity from renewable sources, natural gas, and coal, while the powertrains include internal combustion engines (ICEs), hybrid electric, and battery electric vehicles. The results indicate that switching to natural gas resulted in resource conservation of 33% and emission reduction of 52%, and the proposed dedicated CNG and CNG hybrid electric powertrain options offered the lowest levelised costs of driving (US$0.27/km and US$0.25/km, respectively).

Electrified transport presented the most significant emissions savings (up to 98%) except for using coal, but the unit-levelised costs were higher than using CNG. The study observed that cost is an important factor and also suggested subsidy removal and other initiatives to promote the adoption of low-carbon fuels and Powertrain alternatives in Nigeria.

Aniegbunem and Kraj (2023) undertook a study that stems from the directive of the University of Saskatchewan's Sustainability Office to transform the campus vehicle fleet as an identified area for curbing GHG emissions and meet the University agenda. The study was organized in partnership with the Sustainability Office and involved an economic benefit analysis of the campus fleet (consisting of 91 ICE vehicles) to determine if it was economically or financially feasible to transition from Internal Combustion Engines (ICEs) or PVs (Petrol Vehicles) to Electric Vehicles (EVs). The findings revealed among other things, that the GHG emissions from the campus fleet could be reduced by 100%, resulting in the removal of 298.1 tCO_2 from the environment. The results show that pursuing sustainable transport transitions in the transportation transition for a university campus is financially and economically viable and should be pursued vigorously. The work provides examples and evidence to advance policy recommendations to aid the effective and efficient transitioning of the transportation sector, specifically for communities at the scale of university campuses.

Razmjoo *et al.*, (2022) conducted a study that aimed to highlight and analyze the most critical aspects of the expansion of the electric vehicle market, regarding technologies, characteristics, advantages and disadvantages, opportunities, and barriers in Europe. The study analyzed the progress of EVs based on technology, policy, and government measurements. It provides comprehensive information on EVs and perspectives that are critical to policymakers, car manufacturers, consumers, and the community. To achieve favourable results, the study suggests that governments should invest in developing electric vehicles and battery technologies, provide subsidies, and develop charging infrastructure. Furthermore, by analyzing current EV sales in ten countries around the world, the operating costs of EVs was assessed. Overall EV cost of ownership is influenced by grid electricity price, cost of financing, location, carbon tax, wind speed, and solar insolation.

Shah *et al.*, (2022), through the transition theory lens, reviewed the national policy measures and broad clean transportation targets that small island countries are implementing to encourage electric mobility deployment. According to information compiled for 18 small island countries, there was a growing trend in electric vehicle and infrastructure development incentives among broader clean transportation transformation policies and nationally determined contribution targets; and large country-to-country variations in enabling conditions to smoothen EV transition. The study shows that small island countries are not uniform but instead are very dispersed across the transition S-curve. The review, therefore, finds that the mobility transition requires island-specific approaches and solutions that will accentuate critical policy and management elements for fostering transitions.

Aggarwal and Singh (2021) observed that fossil fuels vehicles contribute immensely to GHG emissions, and relatively, electricity is a more efficient way to power transport vehicles. The study provides comprehensive information on all aspects of electric vehicles (EVs) and observes that with lower tailpipe emissions, EVs are an immediate answer to the problem of environmental degradation.

Hussaini and Scholz (2017) uses analytical frameworks of multi-level and multi-phase perspectives to explore low carbon transition pathways for the UK road transport system. The results showed that the transformation pathway was mainly characterized by the adoption of biofuel blends and hybrid electric vehicles, as we as niche technologies. Beyond this pathway, they have shown that the likely pathway sequence to full decarbonization will be transformation-substitution-de-alignment/re-alignment pathways. However, the dynamics that can favour a smooth process of this sequence will demand a range of active niche technologies and strong government interventions.

From the above literature survey, we can see that there are a lot of studies on road transport system transitions and the adoption of low emission vehicles such as CNG, EVs, etc. in different parts of the world, including Nigeria. These works mainly focus on GHG emissions by road vehicles and ways to decarbonise the sector, the transition scenarios involved, but none has addressed the tendency of LCV adoption by consumers and the likely transition pathway(s) involved in Nigeria's road transport system. Therefore, the novelty of this work contributes to understanding the future likely LCV options, the pathway mechanism and as a result, inspire the best policy approach for the transition.

3.0 LOW CARBON VEHICLE (LCV) TECHNOLOGY OPTIONS FOR ROAD TRANSPORT

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For over a century, the Nigerian road sector has been characterized by conventional vehicles powered by fossil fuel internal combustion engine (ICE) and thus, the regime can be described as a case of a stabilized regime with high resistance and resilience to alternative innovations (Geels, 2012; Geels *et al.*, 2012; Geels, 2014). Due to the fact that our conventional fossil fuel vehicles (FFVs) release greenhouse gases (GHGs) into the environment, and in order to reduce such emissions, it is advisable to focus on low carbon technologies that will help in reducing or eliminating such carbon emissions from the environment. According to the European Commission (2022) and US Department of Energy (2021), potential alternative low emission transport fuels available for future large-scale adoption include the following:

- Methane-based fuels (e.g. Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG), Biomethane and E–gas). All transport modes can use it, with the exception of aviation.
- Propane and butane-based fuels (e.g. Liquefied Petroleum Gas (LPG) and BioLPG), used only in road transport.
- Alcohols, Ethers and Esters (e.g. Ethanol, Butanol, Methanol, Ethanol-based blend of 95 % (ED95)). All transport modes can use it, with the exception of aviation.
- Synthetic paraffinic and aromatic fuel (e.g. Hydrotreated Vegetable Oil (HVO) and Gas to Liquid (GTL)). All transport modes can use it, including aviation.
- Hydrogen (e.g. CH2, LH2, NH3). All transport modes can use it.
- Electricity (e.g. Battery Electric Vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs), Hybrid Electric Vehicles (HEVs)). More suitable for passenger cars and light duty vehicles.

The US Department of Energy (2021) prioritises the following alternative fuels for transportation; Biodiesel, Ethanol, Natural gas (CNG/LNG), Propane (LPG), Electricity and Hydrogen (HFC). All hydrocarbon based or biofuel based vehicles operate much like conventional vehicles with spark-ignited ICEs. The engine functions the same way as a gasoline/diesel engine. For Electric Vehicles (EVs), electricity is used to power the vehicles, including both all-electric vehicles, also called battery-electric vehicles (BEVs), and plug-in hybrid electric vehicles (PHEVs). BEV is chosen for this research because it produces no tailpipe emissions and represents vehicles that run on 100% electricity (Table 1).

Table 1: Performance-cost Comparison of Various LCVs Relative to Fossil Fuel Vehicles

S/N	Vehicle technology	Fossil fuels vehicles (FFVs)		Biofuel vehicle (BFV)		Battery Electric Vehicle (BEV)	Liquefied Petroleum Gas vehicle (LPGV)	Compressed Natural Gas Vehicle (CNGV)	Hydrogen Fuel Cell Vehicle (HFCV)
	Fuel type	**Gasoline**	**Diesel**	**Ethanol**	**Biodiesel**	**Electricity**	**Propane**	**Natural gas**	**Hydrogen**
1	**Mass density (kg/m3)**	730[a]	830[a]	789[a]	880[a]	-	510[a]	0.768[b]	0.0838[b]
2	**Energy density (MJ/kg)**	44[a]	42.8[a]	27[a]	37[a]	3.60 (/kWh)[c]	46.28[a]	46.89[c]	114.4[d]
3	**Energy density (MJ/l)**	32[a]	36[a]	21[a]	33[a]	3.60 (/kWh)[c]	24[a]	12[d]	0.32[d]
4	**Energy Cost ($/gallon)**	3.69[e]	4.25[e]	2.98[e]	4.95[e]	0.174 (/kWh)[f]	3.63[e]	2.99 (/GGE)[e]	15 (/kg)[g]
5	**Performance - Cost (MJ/$)**	32.83	32.06	26.68	25.24	20.69	25.03	40.51	7.63

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6	**Emissions intensity (gCO_2e/MJ)**	72.5[(a)]	73.7[(a)]	70.6[(b)]	76.3[(a)]	0	65.4[(a)]	56.9[(b)]	0[(b)]
7	**Carbon content (%)**	87[(a)]	86[(a)]	52[(a)]	77[(a)]	0	82[(a)]	75[(a)]	0[(b)]
8	**Physical benefit**	1+1[(d)]	1+1.12[(d)]	0.6+0.7[(d)]	0.84+1[(a)]	-	1+0.86[(d)]	1.3+0.37[(d)]	-
9	**Economic benefits**	1.00	0.98	0.81	0.77	4.00	0.76	1.23	2.00
10	**Environmental benefits**	1+1	0.98 +1.01	1.03 +1.67	0.95 +1.13	-	1.11+1.06	1.27+1.16	-
11	**Overall benefits**	5	5.09	4.81	4.69	0.65+…	4.79	5.33	2.88+…

Notes: All energy prices are international (US) prices; 1 US gallon = 3.7854 L[(b)].
Sources: [(a)]Forest Research (2023); [(b)]Staffell (2011); [(c)]US Department of Energy (2021); [(d)]US Energy Information Administration (2014); [(e)]US Department of Energy (2023); [(f)]GlobalPetrolPrices (2023); [(g)]PIN (2023).

Natural gas can be used as fuel for transport either in compressed (CNG) or liquefied (LNG) form. In vehicle applications, the main advantage of LNG over CNG is that it has higher energy density. However, LNG is more complicated, involves higher costs of production and transportation, hence, is less cost-effective than CNG. Also, LNG fuelling stations require more complex technicalities and facilities to handle, and are not widely available. There are far more available CNG stations than LNG stations even in advanced countries. LNG is also more hazardous than CNG and there is the need for LNG vehicles to vent off fumes. The lack of LNG cooling systems in LNG vehicles causes heat gains in the storage tanks which causes vaporization of the fuel (CREG, 2018; Cummins, 2022; Shipleyenergy, 2023).

The energy and emissions characteristics of the various LCVs depend on the fuel type and the vehicle technology involved. Table 1 indicates the physical, economic and environmental benefits of the selected LCVs in terms of their fuels in relation to the conventional fossil fuels. Electricity for BEVs is assumed to be generated from low carbon or renewable sources, and does not take upstream emissions into consideration. Biofuel is assumed to be sourced in a sustainable manner, with net-zero emissions effects. Physical/technical benefits of the LCV fuels are the summation of the energy densities (MJ/kg and MJ/l) indexed to gasoline (Forest Research, 2023; US Energy Information Administration, 2014). Economic benefit refers to gasoline relative Performance-Cost factors, Environmental benefit refers to gasoline relative Emissions intensities.

4.0 METHODOLOGY

4.1 The Study Area

The study was conducted in Maiduguri Metropolis, the Capital city of Borno State, Nigeria. The city is located between latitudes 11°46' to 11°53'N and longitudes 13°2' to 13°13'E (Google Earth, 2022). Borno state is bordered by the Republic of Niger to the North, Atlantic Ocean to the south, Benin Republic to the West, Chad to North East and Cameroon to the East. The region was home to the Kanem-Bornu Empire for centuries. Currently, the city has a landmass mass of 105.5 km^2 (0.15% of the state's landmass and 0.011% of the country's landmass) and a population of around 845,000 people (which is about 15% of the state's population and 0.377% of country's population), with a population growth rate of +2.8%/yr (City Population, 2023; Macrotrends, 2023a, 2023b; National bureau of statistics, 2011; World Population Review, 2023a, 2023b).

4.2 Data collection

To ensure quality data, we conducted semi-structured interviews/surveys with the relevant actors involved in the technology, market and use of Low Carbon Vehicle (LCV) technologies in Nigeria. The data collection adopted in this research was a combination of qualitative and quantitative primary data collection that used interview/survey approach. This was done by visiting government organizations such as ministries, departments and agencies (MDAs) as well as academic institutions. Markets and industries such as vehicle dealer, spear part seller and mechanics; Civil society considering households of different education backgrounds; and Road transport vehicle operators/users of passenger cars (PCs), light-duty vehicles (LDVs) and heavy duty-vehicles (HDVs) were also interviewed during the data collection process. We adopted face-to-face interview approach, and considered the use of indicative questions as suitable for this investigation, which provided insight of the system perspective. The approach proved to be an efficient method for the opportunity assessment of emerging innovations within the road transport system.

Three sample sub-sectors were chosen in each of the selected data source sectors. In the Government, state Ministry of Transport (MoTrp), Ministry of Energy (MoEng) and Ministry of Environment (MoEnv) were chosen. Data on the feasibility of adopting LCVs as against FFVs were collected for the five LCV technologies (Biofuel vehicle BFV, Battery electric vehicle BEV, Liquefied petroleum gas vehicle LPGV, Compressed natural gas vehicle CNGV, and Hydrogen fuel cell vehicle HFCV), under three cost conditions (when LCVs are costlier than FFVs, when LCVs are same cost as FFVs, and when LCVs are cheaper than FFVs), on a scale of 1-5 and expressed in percentages. Similar approach was adopted in other sectors; Organizations (Health, Education and Communication), Technical Industry (Vehicle Dealers VD, Spare Part-sellers SPS and Mechanics), Vehicle Users (Passenger vehicles PC, Light duty vehicles LDV and Heavy duty vehicles HDV), and Civil Society (Educated, Semi-educated and Un-educated), as shown in the Appendix. A sample of ten (10) respondents were interviewed for each of the subsectors.

4.3 Method of data analysis

The method used in analyzing and presenting the data is statistical histogram, by comparing conventional FFVs and the alternative LCVs in the different data source sectors in Maiduguri metropolis under different economic conditions. Ten (10) respondents were chosen for each of the subsectors. For the analysis, a histogram is then plotted with the primary data obtained from the interviews on the relative LCVs' performance to FFVs.

5.0 RESULT AND DISCUSSION

The primary data for the future of Low Carbon Vehicles (LCVs) were collected and organized in comparison with the conventional ICE Fossil Fuel Vehicles (FFVs) under various cost conditions in Maiduguri metropolis (Appendix) and summarized in the Table 2.

5.1 Tendency for LCV Adoption from Sectoral and Sub-Sectoral Perspective

The analysis of the results show that there is an increasing tendency for LCV adoption in the road transportation sector for all sectors of the society, from LCV > FFV, through LCV = FFV, to LCV < FFV scenario. For the public sector, the three ministries show very similar trend and degree for LCV adoption across the three cost scenarios. However, ministries of transport and environment show greater similarity in this respect. MoTrp shows that for LCV > FFV scenario, BEV appears to be the option with the highest transition tendency (46%), followed by CNGV (40%), LPGV (34%), BFVs (32%), and finally HFCV (22%). For LCV = FFV, CNG (70%), LPG (64%), BEV (62%) vehicles show high acceptability levels, while BFV (54%) and HFCV (40%) still show lower acceptability levels. For the third cost scenario (LCV < FFV), CNGV (84%), LPGV (80%), and BEVs (82%) still show higher acceptability levels, while BFV (62%) and HFCV (58%) options still show lower acceptability levels. MoTrp data show that CNGV, LPGV, and EV are the most preferred and compete for the highest position for transition opportunities with BFVs closely following up with them, while HFCV show distant last option.

For Ministry of Energy (MoEng), competition among the various LCVs show similar trend to MoTrp for LCV > FFV, but BFV tends to overtake all other options under the LCV = FFV and LCV < FFV cost scenarios, with BEV, LPGV and CNGV following closely, but with HFCV coming closer in all the cost conditions. Ministry of Environment (MoEnv) also show similar trend to MoTrp, for all the three scenarios, with BFV and BEV fronting the options, then LPGV and CNGV, followed by HFCV. A similar trend is also observed with the average for the three sub-sectors/ministries, i.e. the overall public sector. Similarly and generally, other sub-sectors/sectors also show similar preference patterns for the LCVs under the three scenarios. Figure 1 shows the averages of LCV preferences for the different societal sectors under the three cost scenarios.

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Table 2: Tendency of LCV Adoption in Different Societal Sectors

Sector	Sub-sector	When LCVs are costlier than FFVs (LCV > FFV)					When LCVs are same cost as FFVs (LCV = FFV)					When LCVs are cheaper than FFVs (LCV < FFV)				
		LCV options (%)					LCV options (%)					LCV options (%)				
		Biofuel vehicle (BFV)	Battery Electric Vehicle (BEV)	LPG vehicle	CNG vehicle	HFC vehicle	Biofuel vehicle (BFV)	Battery Electric Vehicle (BEV)	LPG vehicle	CNG vehicle	HFC vehicle	Biofuel vehicle (BFV)	Battery Electric Vehicle (BEV)	LPG vehicle	CNG vehicle	HFC vehicle
Government	MoTrp	32	46	34	40	22	54	62	64	70	40	62	82	80	84	58
	MoEng	46	48	62	58	42	72	60	60	58	46	88	74	76	72	68
	MoEnv	42	42	38	36	26	62	64	50	56	48	82	82	74	72	70
	Average	**40**	**45**	**45**	**45**	**30**	**63**	**62**	**58**	**61**	**45**	**77**	**79**	**77**	**76**	**65**
Organizations	Health	30	34	36	34	24	56	58	60	58	62	82	94	96	98	84
	Education	22	30	36	28	14	88	88	84	82	74	98	94	96	96	90
	Commun.	10	20	18	20	10	50	42	42	42	42	82	92	90	92	76
	Average	**21**	**28**	**30**	**27**	**16**	**65**	**63**	**62**	**61**	**59**	**87**	**93**	**94**	**95**	**83**
Technical Industry	Veh Deal.	34	38	32	36	30	62	76	56	64	56	84	86	86	82	82
	SPS	12	26	20	22	12	54	54	54	54	48	88	90	98	94	78
	Mech	30	30	32	28	28	58	72	78	74	58	80	96	76	90	78
	Average	**25**	**31**	**28**	**29**	**23**	**58**	**67**	**63**	**64**	**54**	**84**	**91**	**87**	**89**	**79**
Vehicle users	PCs	40	34	18	20	18	60	50	48	38	40	90	82	86	78	72
	LDVs	32	30	22	24	14	58	54	46	56	42	90	90	88	90	84
	HDVs	30	28	20	22	12	60	54	44	54	46	92	88	88	90	84
	Average	**34**	**31**	**20**	**22**	**15**	**59**	**53**	**46**	**49**	**43**	**91**	**87**	**87**	**86**	**80**
Civil Society	Educated	18	32	26	38	12	62	62	60	76	50	90	86	82	88	82
	Semi-edu	18	14	14	18	10	34	40	28	40	26	82	82	78	86	68
	Un-edu.	6	36	24	20	12	46	62	50	44	32	78	90	80	84	68
	Average	**14**	**27**	**21**	**25**	**11**	**47**	**55**	**46**	**53**	**36**	**83**	**86**	**80**	**86**	**73**
Overall average (%)		**27**	**32**	**29**	**30**	**19**	**58**	**60**	**55**	**58**	**47**	**84**	**87**	**85**	**86**	**76**

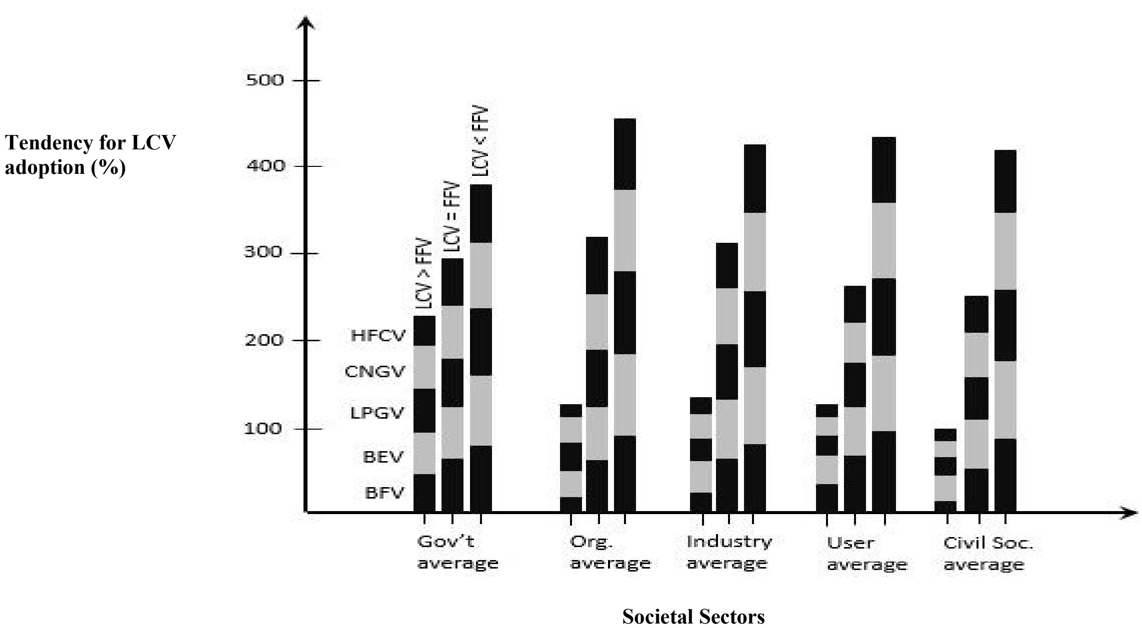

Figure 1: Assessment of LCVs' Preference over FFVs Under Different Cost Conditions in Different Societal Sectors in Maiduguri

5.2 Tendency for LCV Adoption from Societal Perspective

Figure 2 shows the overall average preferences for the overall society for each of the LCVs and for each cost scenario. As expected, for LCV > FFV scenario, the chances of a successful transition to LCVs are very slim, with a maximum of around 30%, and this is a clear depiction of our current situation in Nigeria, and in almost all parts of the world. For the LCV = FFVs condition, there is close to 60% chance for a successful transition to LCVs in Nigeria. With LCV < FFVs condition, the chances for the transition are as high as over 80%. This proves that relative costs of LCVs play a major role in ensuring the transition or otherwise of LCVs in the road transport sector.

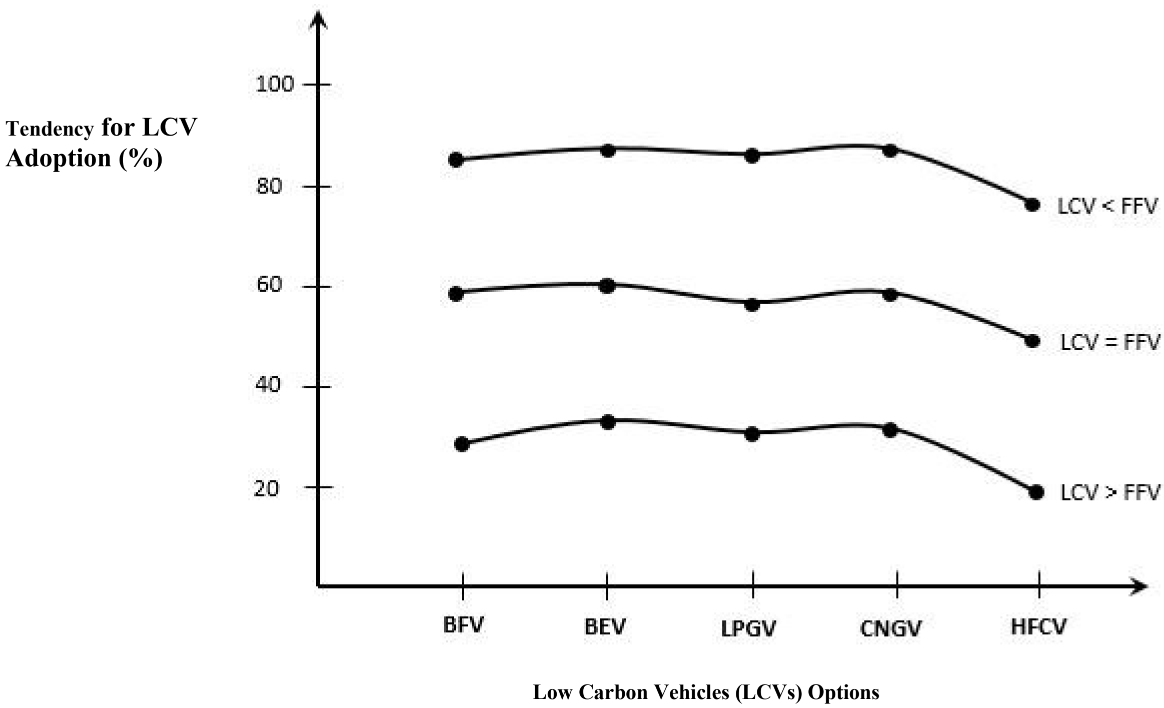

Figure 2: Tendency for LCV Adoption at the Societal Level for Different Cost Conditions

Interestingly, the transition tendency patterns for all the three cost conditions show similar shapes, that of an elongated letter M, slightly tilted to the right. The shoulders of the M-shape indicate that BEV and CNGV stand a better chance for the transition among the five options. The tilting of the graph to the right indicates that BFVs are preferred over hydrogen vehicles (HFCVs) and holds similar future with LPG vehicles. For transition tendency order, we may consider the average percentages for each of the LCV options irrespective of cost condition, to reveal the sequence of LCV preference. A computation of the average percentages (Table 2) reveals the following order: BEV/CNGV (60/58%) – BFV/LPGV (56%) – HFCV (47%).

5.3 Comparative Assessment of LCVs' Overall Performance from Literature

In any socio-technical transition, the emerging innovation usually has some potential advantages over the regime technology, especially techno-economic, that make it the most preferred option for adoption. Energy cost and density, weight, and size of onboard energy storage are important characteristics of transportation fuels. Cheaper fuels have more advantage in energy transition, however, fuels that are heavy and/or that require large, heavy, or expensive storage can reduce space available in the vehicle, weigh it down (making it less efficient), or make it too costly to operate, despite being cheap. The five LCV technology options under the study have various merits and demerits in terms of energy cost, techno-economic and environmental performances, and compete among themselves and between them and fossil fuel vehicles (FFVs).

Figure 3 compares energy densities (both per unit volume and per unit weight) for the various transportation fuels. According to US Energy Information Administration (2014), alternative low carbon fuel options may have more energy per unit weight, but none have more energy per unit volume than gasoline and diesel fuels. Table 1 presents the relevant information regarding the operating costs, physical performance and environmental implications of the fuels for the various LCVs under consideration. These performances are indexed against gasoline, being 1 in value. Based on this information, a summation of the physical, economic and environmental benefits of each of the LCVs in terms of their fuels was made to obtain the overall vehicle performance. Figure 4 presents the overall performance for LCVs from the literature, concerning their operations relative to gasoline vehicles.

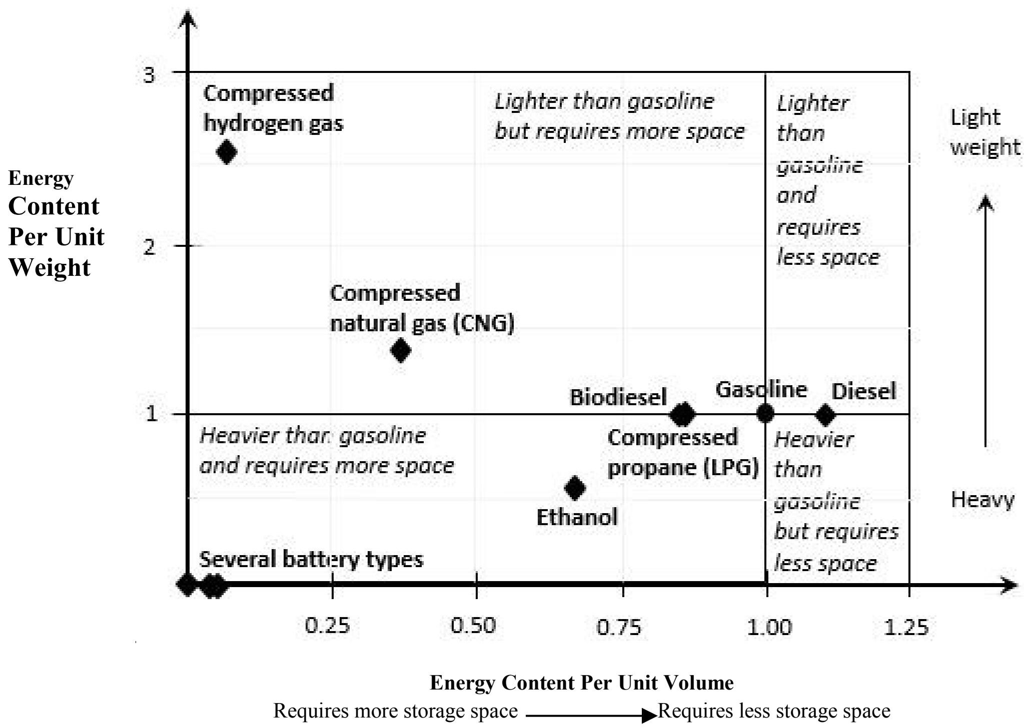

Figure 3: Energy Density Comparison of Alternative Low Carbon Transportation Fuels Indexed to Gasoline = 1 (Forest research, 2023; US Energy Information Administration, 2014)

Battery electric vehicle (BEV), CNG and HFC vehicles show better overall performance when compared to gasoline FFV. The BEV and HFCV performance was due to their fuel economy and limitless environmental benefits as a result of net-zero emissions (where the electricity and hydrogen are generated from clean renewable sources). However, the costs of batteries, fuel cells and hydrogen storage are excessively expensive and the availability of refueling and charging facilities is extremely limited. In addition, the better fuel economy of these vehicles does not compensate for the lower fuel densities of hydrogen and various battery types that result in limited driving range relative to gasoline-powered vehicles. Unlike CNG vehicle, these limitations do not support the tendency for BEV and HFCV as LCV options in a transition process.

Similarly, fossil fuel vehicles (FFVs) and LPG vehicle show competing performance with gasoline vehicle. Where biomass is used in a sustainable manner, biofuel vehicles (BFVs) also show limitless environmental benefits, but with less physical and economic performance compared to gasoline vehicle. Performance-cost factors are always the most preferred considerations among consumers when adopting technical assets. This factor favours CNG vehicle which indicates high economic benefits among the options. This option is followed by ethanol BFV, and then LPGV. From the above observation, CNG, Biofuel and LPG vehicles offer promising alternatives with competitive advantages to FFVs. BEV and HFCV vehicles are not viable LCV options for now and in the near future due to their high initial costs. The likely order of consumer preference from literature is therefore thus: CNGV – BFV/LPGV – BEV/HFCV.

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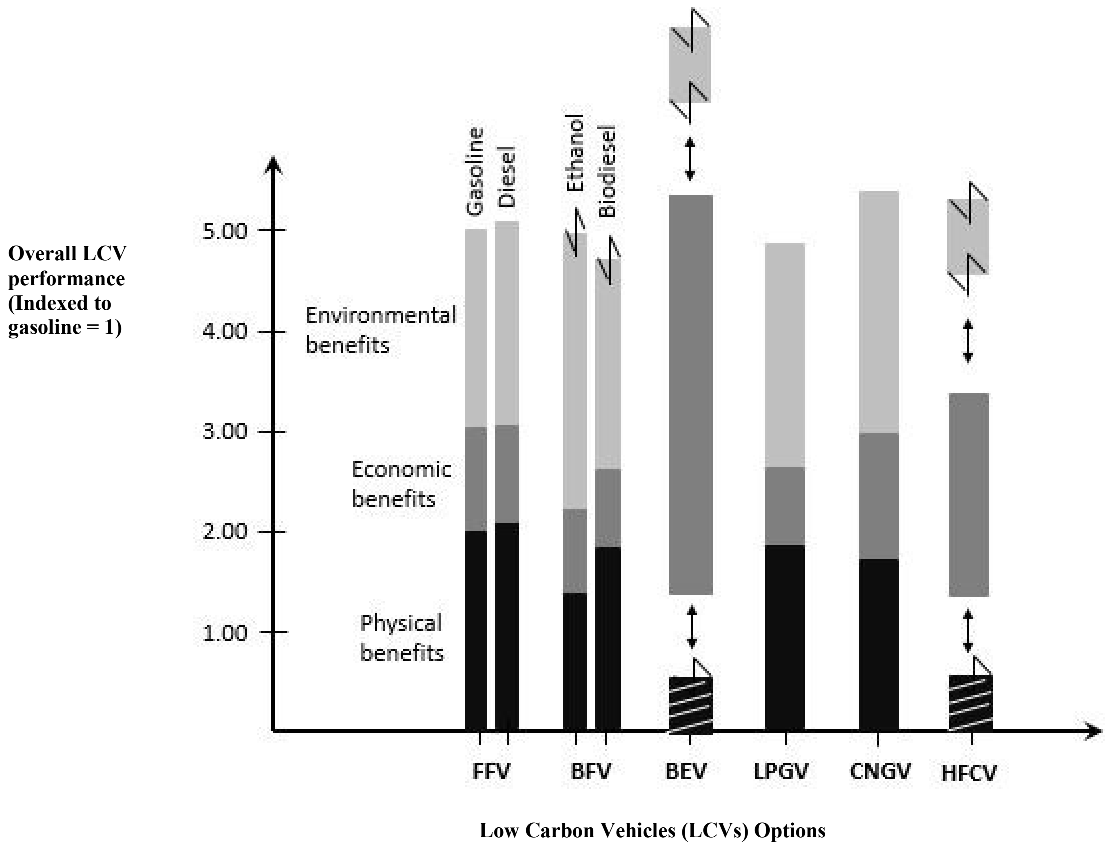

Figure 4: Relative Overall Performance of Different LCVs – Indexed to Gasoline = 1 (Table 1, Section 3.0)

This order looks very similar to that from the primary research data in Section 5.2 (BEV/CNGV – BFV/LPGV – HFCV), with BEV interchanging positions from end to first. This is clearly a result of the lack of emphasis on the initial excessive battery cost associated with BEVs during data collection. Nigeria has enormous hydrocarbon resources (methane and propane) and massive land for biomass production that can sustain a transition to low emission transport system. However, the high technical capacity in CNG and LPG production and processing in Nigeria compared to biofuels favours CNGV and LPGV as a better option when combined with the right policy.

6.0 CONCLUSION AND RECOMMENDATION

In this paper, a study on the feasibility and likely scenario of a transition to low carbon vehicles (LCVs) in Nigeria's road sector was conducted, with Maiduguri Metropolis as a case study. Different sectors in the society including government MDAs, industries, markets, vehicle users, etc. were used as primary sources of data. The data collection focused on the following five LCV technologies, namely; 1. Biofuel vehicles, 2. Electric vehicles, 3. Liquefied petroleum gas (LPG) vehicles, 4. Compressed natural gas (CNG) vehicles, and 5. Hydrogen vehicles, while the stakeholders were interviewed to assess their level of acceptability of these LCVs based on the following three conditions; 1. When LCVs are costlier than FFVs, 2. When LCVs are same cost as FFVs, and 3. When LCVs are cheaper than FFVs.

Based on the results obtained from this study, the degree of acceptability of LCVs in the society (measured in percentages) was highest when they are cheaper than the conventional fossil fuel vehicles (FFVs). Thus, economic factors play a very vital role in LCV transition; demand for LCVs is higher and the transition is promising when the LCVs are cheaper than FFVs. With the right political will, what is clear about the transition scenario is that it is likely to exhibit a "de-alignment/realignment" pathway, involving CNG and LPG ICE vehicles, and maybe BFVs (depending on Nigeria's future technical capacity level in biofuels), during niche technology experimentation. A high technical capacity in biofuel will mean a prolonged competition between BFVs and CNGV/LPGV options. The development of the CNG vehicle options can be achieved through the development of natural gas resource in Nigeria, for a smooth transition. This is very much in line with the adoption of natural gas as a transition fuel by the Nigeria Energy Transition Plan (ETP) and the European Union (EU).

However, for Nigeria and many other developing countries, lack of finance represent one of the most formidable barriers to fast tracking action on clean energy and achieving a green transition in the economy. For a country with a high rate of poverty, high debt levels, and a less than impressive experience in attracting international finance, achieving this scale of investment represents quite a challenge. Interestingly, the adoption of natural gas as a transition fuel by the EU is a major boost for Nigeria (with commercially abundant gas reserves that can be harnessed) to broaden its fiscal space for low carbon investments, to help the country's transition to LCVs and net-zero emissions by 2060. Furthermore, the establishment of the National Climate Change Council (NCCC) and Climate Change Fund present a veritable platform and opportunity to direct efforts and to mobilise resources towards the delivery of far-reaching green investment objectives.

Nigeria can take advantage of its climate commitments, pledges and policy statements to mobilize finance and ensure technology development and transfer into its road transport system. These pledges include UNFCCC, Kyoto protocol, Paris agreement and the Nationally Determined Contributions (NDC), with a set of climate change action plans. Opportunities do exist to truly unlock climate finance from the various viable sources. Where the institutions are proactive and strategic, they can play a crucial role in catalysing carbon finance for the country.

Various key options are available for Nigeria to upscale public, private and international climate finance if the government is to ensure a successful transition away from fossil fuel vehicles to low emission alternatives in the road transport sector. Some of the available sources of funding for Nigeria include Federal Government's annual appropriation (through green the budgeting), Green bonds, Greening National and Subnational Borrowing Plan, subventions, grants, donations, fees, and fines from private and public entities. This will no doubt require the discipline of pipeline disclosure, green credential certification, project implementation and reporting. This can only be achieved by building the enabling environment; strong institutional capacity, staffed with people of high credibility, and characterized by an international standard of transparency and accountability.

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APPENDIX:

SURVEY DATA

Table A1: Comparing FFVs to LCVs in the Government MDAs under different cost conditions

Government agencies	Respondent	When LCVs are costlier than FFVs					When LCVs are same cost as FFVs					When LCVs are cheaper than FFVs				
		LCV options					LCV options					LCV options				
		Biofuel vehicle	Electric vehicle	LPG vehicle	CNG vehicle	H2 vehicle	Biofuel vehicle	Electric vehicle	LPG vehicle	CNG vehicle	H2 vehicle	Biofuel vehicle	Electric vehicle	LPG vehicle	CNG vehicle	H2 vehicle
Ministry of transport	1	1	2	1	2	0	3	4	3	4	2	4	4	4	4	4
	2	1	3	2	2	1	3	4	4	4	2	3	4	5	5	3
	3	2	3	2	2	1	2	3	4	4	2	3	4	4	5	2
	4	2	2	2	2	1	2	3	4	4	1	2	3	3	3	2
	5	1	2	2	2	1	2	3	4	4	2	2	3	4	4	3
	6	2	2	2	2	2	3	3	3	3	3	4	4	4	4	4
	7	2	2	1	2	2	3	3	2	3	2	3	5	3	4	3
	8	2	2	1	2	1	3	3	2	3	2	3	5	4	4	2
	9	2	3	1	2	0	3	3	3	3	2	4	5	4	5	3
	10	1	2	3	2	2	3	2	3	3	2	3	4	5	4	3
	Avr	1.6	2.3	1.7	2	1.1	2.7	3.1	3.2	3.5	2	3.1	4.1	4	4.2	2.9
	%	32	46	34	40	22	54	62	64	70	40	62	82	80	84	58
Ministry of energy	1	2	3	3	4	1	5	3	3	5	2	5	5	5	5	5
	2	2	3	2	3	2	4	4	4	3	2	4	5	4	4	3
	3	2	2	3	3	2	4	3	3	4	2	4	3	3	4	3
	4	3	2	3	4	2	3	4	4	3	3	5	3	4	3	3
	5	2	2	4	4	3	4	3	4	3	2	5	4	4	3	3
	6	2	2	3	3	2	3	2	3	2	3	3	3	4	3	3
	7	3	3	3	2	3	3	3	2	2	3	4	4	3	4	3
	8	3	2	4	2	3	3	2	3	2	2	5	3	4	4	4
	9	2	3	3	2	2	4	3	2	2	2	5	3	4	3	4
	10	2	2	3	2	1	3	3	2	3	2	4	4	3	3	3
	Avr	2.3	2.4	3.1	2.9	2.1	3.6	3	3	2.9	2.3	4.4	3.7	3.8	3.6	3.4
	%	46	48	62	58	42	72	60	60	58	46	88	74	76	72	68
Ministry of environment	1	2	3	2	3	1	4	5	4	5	3	5	5	5	5	5
	2	2	2	2	2	1	3	4	3	4	2	4	5	4	4	3
	3	2	2	2	2	1	3	3	2	2	2	4	4	3	3	3
	4	2	2	2	2	1	2	2	2	2	2	3	3	3	3	3
	5	3	2	3	2	2	4	3	3	3	3	5	4	4	4	4
	6	2	2	2	2	1	3	3	3	3	2	4	4	4	4	3
	7	2	2	1	1	1	3	3	2	2	2	4	4	3	3	3
	8	2	3	2	1	2	3	4	2	2	3	4	5	5	3	4
	9	2	1	2	2	1	3	2	2	3	2	4	3	3	4	3
	10	2	2	1	1	2	3	3	2	2	3	4	4	3	3	4
	Avr	2.1	2.1	1.9	1.8	1.3	3.1	3.2	2.5	2.8	2.4	4.1	4.1	3.7	3.6	3.5
	%	42	42	38	36	26	62	64	50	56	48	82	82	74	72	70
Avr %		**40**	**45**	**45**	**45**	**30**	**63**	**62**	**58**	**61**	**45**	**77**	**79**	**77**	**76**	**65**

Notes:

- Tendency of LCV acceptance scale: 0 – 5 (0 being impossible and 5 being very possible)
- Costs emphasis operating expenditure

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Table A2: Comparing FFVs to LCVs in other organizations under different cost conditions

Organizations sub-sector	**Respondent**	**When LCVs are costlier than FFVs**					**When LCVs are same cost as FFVs**					**When LCVs are cheaper than FFVs**				
		LCV options					LCV options					LCV options				
		Biofuel vehicle	Electric vehicle	LPG vehicle	CNG vehicle	H2 vehicle	Biofuel vehicle	Electric vehicle	LPG vehicle	CNG vehicle	H2 vehicle	Biofuel vehicle	Electric vehicle	LPG vehicle	CNG vehicle	H2 vehicle
Health	1	2	2	2	2	2	3	2	3	3	2	5	5	5	5	5
	2	1	1	2	2	2	4	3	3	3	3	5	5	5	5	5
	3	2	2	3	2	2	4	3	3	3	4	4	5	5	5	4
	4	1	2	2	2	2	3	3	3	3	4	4	5	5	5	4
	5	2	1	1	1	1	2	3	2	2	2	3	4	4	5	3
	6	2	2	2	2	1	3	3	3	3	3	3	4	4	4	5
	7	2	2	2	2	1	3	3	4	3	4	4	5	5	5	4
	8	1	2	2	2	1	2	3	3	3	3	4	5	5	5	4
	9	1	1	1	1	0	2	3	3	3	3	4	4	5	5	4
	10	1	2	1	1	0	2	3	3	3	3	5	5	5	5	4
	Avr	1.5	1.7	1.8	1.7	1.2	2.8	2.9	3	2.9	3.1	4.1	4.7	4.8	4.9	4.2
	%	30	34	36	34	24	56	58	60	58	62	82	94	96	98	84
Education	1	0	2	0	1	0	5	5	5	5	4	5	5	5	5	5
	2	3	3	3	3	2	5	4	4	4	4	5	5	5	5	5
	3	2	3	2	3	3	5	5	5	5	5	5	5	5	5	5
	4	0	1	2	1	0	4	5	3	3	3	5	5	5	5	4
	5	0	0	2	1	0	4	4	4	4	4	5	4	4	4	4
	6	1	1	2	1	0	3	3	3	3	3	5	4	4	4	4
	7	1	1	2	0	0	5	4	4	4	4	5	5	5	5	5
	8	2	1	2	2	1	5	5	5	4	4	5	5	5	5	5
	9	2	1	2	1	1	4	4	4	4	3	4	5	5	5	4
	10	0	2	1	1	0	4	5	5	5	3	5	4	5	5	4
	Avr	1.1	1.5	1.8	1.4	0.7	4.4	4.4	4.2	4.1	3.7	4.9	4.7	4.8	4.8	4.5
	%	22	30	36	28	14	88	88	84	82	74	98	94	96	96	90
Communication	1	0	1	1	1	1	3	2	3	2	2	5	4	4	4	3
	2	0	1	1	1	0	3	2	2	2	2	4	5	5	5	4
	3	1	1	1	1	0	3	2	2	2	2	4	5	5	5	4
	4	1	1	1	1	1	3	2	2	2	2	4	4	4	4	4
	5	1	1	1	1	0	3	2	2	2	2	4	5	5	5	4
	6	0	1	1	1	1	2	3	2	2	2	3	4	3	4	3
	7	0	1	0	1	0	2	2	2	1	1	3	4	4	4	3
	8	1	1	1	1	1	2	2	2	2	2	5	5	5	5	5
	9	1	1	1	1	0	2	2	2	4	4	5	5	5	5	4
	10	0	1	1	1	1	2	2	2	2	2	4	5	5	5	4
	Avr	0.5	1	0.9	1	0.5	2.5	2.1	2.1	2.1	2.1	4.1	4.6	4.5	4.6	3.8
	%	10	20	18	20	10	50	42	42	42	42	82	92	90	92	76
Avr %		**21**	**28**	**30**	**27**	**16**	**65**	**63**	**62**	**61**	**59**	**87**	**93**	**94**	**95**	**83**

Notes:

- Tendency of LCV acceptance scale: 0 – 5 (0 being impossible and 5 being very possible)
- Costs emphasis operating expenditure

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Table A3: Comparing FFVs to LCVs in the Industry under different cost conditions

Industry subsector	Respondent	When LCVs are costlier than FFVs					When LCVs are same cost as FFVs					When LCVs are cheaper than FFVs				
		LCV options					LCV options					LCV options				
		Biofuel vehicle	Electric vehicle	LPG vehicle	CNG vehicle	H2 vehicle	Biofuel vehicle	Electric vehicle	LPG vehicle	CNG vehicle	H2 vehicle	Biofuel vehicle	Electric vehicle	LPG vehicle	CNG vehicle	H2 vehicle
Vehicle dealers	1	2	2	1	2	2	4	4	4	4	3	5	5	5	5	5
	2	2	2	2	2	2	3	4	3	2	4	5	4	5	4	5
	3	2	1	2	1	1	3	4	3	4	2	3	4	4	3	4
	4	2	2	2	1	1	3	3	2	2	2	4	3	3	4	3
	5	1	2	2	2	1	2	3	2	2	2	3	4	3	4	3
	6	2	2	1	2	2	3	4	3	3	2	4	5	5	4	3
	7	2	2	1	2	1	4	4	3	4	3	4	4	5	4	4
	8	2	2	2	2	2	3	4	3	4	3	5	4	4	4	5
	9	1	2	1	2	1	3	4	3	3	4	5	5	5	4	4
	10	1	2	2	2	2	3	4	2	4	3	4	5	4	5	5
	Avr	1.7	1.9	1.6	1.8	1.5	3.1	3.8	2.8	3.2	2.8	4.2	4.3	4.3	4.1	4.1
	%	34	38	32	36	30	62	76	56	64	56	84	86	86	82	82
Spear part sellers	1	1	2	1	2	2	4	4	2	3	3	4	4	4	4	4
	2	1	2	1	1	0	3	3	3	3	3	5	5	5	5	5
	3	0	1	2	2	0	3	2	3	3	2	5	4	5	5	4
	4	1	1	2	1	1	3	3	3	3	2	4	4	5	4	5
	5	0	0	1	0	1	2	2	2	3	3	4	3	5	4	4
	6	0	1	1	0	1	3	3	3	3	2	4	5	5	5	3
	7	1	1	0	1	1	2	2	3	2	2	5	5	5	5	4
	8	1	2	1	1	0	3	3	2	2	2	4	5	5	5	3
	9	1	2	1	2	0	2	3	3	3	3	5	5	5	5	4
	10	0	1	0	1	0	2	2	3	2	2	4	5	5	5	3
	Avr	0.6	1.3	1	1.1	0.6	2.7	2.7	2.7	2.7	2.4	4.4	4.5	4.9	4.7	3.9
	%	12	26	20	22	12	54	54	54	54	48	88	90	98	94	78
Mechanics	1	1	1	2	2	1	3	4	4	4	2	4	5	4	5	3
	2	1	2	2	1	1	4	5	5	4	4	5	5	5	5	5
	3	2	1	2	2	1	3	4	5	3	3	4	5	4	5	5
	4	2	2	1	1	2	3	4	3	4	3	4	5	4	5	4
	5	1	2	1	1	1	3	4	3	4	3	4	5	4	4	4
	6	2	1	2	1	2	3	3	4	4	3	4	4	3	4	3
	7	2	2	2	2	2	3	3	3	4	3	4	5	4	4	5
	8	1	2	1	1	1	2	3	4	3	3	4	5	4	5	4
	9	1	1	1	2	2	2	3	4	3	3	4	5	3	4	3
	10	2	1	2	1	1	3	3	4	4	2	3	4	3	4	3
	Avr	1.5	1.5	1.6	1.4	1.4	2.9	3.6	3.9	3.7	2.9	4	4.8	3.8	4.5	3.9
	%	30	30	32	28	28	58	72	78	74	58	80	96	76	90	78
Avr %		**25**	**31**	**28**	**29**	**23**	**58**	**67**	**63**	**64**	**54**	**84**	**91**	**87**	**89**	**79**

Notes:

- Tendency of LCV acceptance scale: 0 – 5 (0 being impossible and 5 being very possible)
- Costs emphasis operating expenditure

Table A4: Comparing FFVs to LCVs in road vehicle users under different cost conditions

Sub-sector	Respondent	When LCVs are costlier than FFVs					When LCVs are same cost as FFVs					When LCVs are cheaper than FFVs				
		LCV options					LCV options					LCV options				
		Biofuel vehicle	Electric vehicle	LPG vehicle	CNG vehicle	H2 vehicle	Biofuel vehicle	Electric vehicle	LPG vehicle	CNG vehicle	H2 vehicle	Biofuel vehicle	Electric vehicle	LPG vehicle	CNG vehicle	H2 vehicle
Passenger vehicles	1	2	2	0	0	0	4	3	2	3	2	5	5	5	4	4
	2	2	1	2	1	1	2	1	2	2	4	4	4	5	5	4
	3	2	2	1	1	1	2	1	2	2	0	4	4	5	5	4
	4	2	2	0	1	1	3	3	2	2	2	4	4	5	4	3
	5	2	2	1	0	1	3	4	3	2	3	5	4	4	3	3
	6	2	2	1	1	0	4	3	3	2	0	5	4	4	4	4
	7	2	2	1	2	1	3	2	3	2	2	4	3	5	4	3
	8	2	1	0	1	1	2	3	2	0	2	4	4	3	3	3
	9	2	1	1	1	1	3	2	3	1	2	5	5	4	3	4
	10	2	2	2	2	2	4	3	2	3	3	5	4	3	4	4
	Avr	2	1.7	0.9	1	0.9	3	2.5	2.4	1.9	2	4.5	4.1	4.3	3.9	3.6
	%	40	34	18	20	18	60	50	48	38	40	90	82	86	78	72
Light duty vehicles	1	2	3	2	2	2	3	3	3	3	2	4	5	5	5	4
	2	2	2	2	1	1	3	3	3	3	2	5	4	4	4	4
	3	2	2	2	2	2	3	2	2	3	2	4	5	5	5	5
	4	2	1	1	1	0	2	2	2	2	1	4	5	5	4	5
	5	2	1	1	1	0	2	2	1	2	1	5	5	4	5	4
	6	1	1	1	1	0	4	3	2	2	4	5	4	4	5	4
	7	1	1	1	1	1	3	4	2	3	2	4	5	4	4	4
	8	1	1	0	1	0	3	2	3	3	2	5	4	5	5	4
	9	1	1	0	1	0	3	3	2	3	2	5	4	4	4	4
	10	2	2	1	1	1	3	3	3	4	3	4	4	4	4	4
	Avr	1.6	1.5	1.1	1.2	0.7	2.9	2.7	2.3	2.8	2.1	4.5	4.5	4.4	4.5	4.2
	%	32	30	22	24	14	58	54	46	56	42	90	90	88	90	84
Heavy duty vehicles	1	1	2	1	1	1	4	3	2	2	4	5	4	5	5	4
	2	2	2	2	1	1	3	3	3	3	2	5	4	4	4	4
	3	2	2	2	2	2	3	2	2	3	2	4	5	5	5	5
	4	2	1	1	1	0	2	2	2	2	1	4	5	5	4	5
	5	2	1	1	1	0	2	2	1	2	1	5	5	4	5	4
	6	1	1	1	1	0	4	3	2	2	4	5	4	4	5	4
	7	1	1	1	1	1	3	4	2	3	2	4	5	4	4	4
	8	1	1	0	1	0	3	2	3	3	2	5	4	5	5	4
	9	1	1	0	1	0	3	3	2	3	2	5	4	4	4	4
	10	2	2	1	1	1	3	3	3	4	3	4	4	4	4	4
	Avr	1.5	1.4	1	1.1	0.6	3	2.7	2.2	2.7	2.3	4.6	4.4	4.4	4.5	4.2
	%	30	28	20	22	12	60	54	44	54	46	92	88	88	90	84
Avr %		**34**	**31**	**20**	**22**	**15**	**59**	**53**	**46**	**49**	**43**	**91**	**87**	**87**	**86**	**80**

Notes:

- Tendency of LCV acceptance scale: 0 – 5 (0 being impossible and 5 being very possible)
- Costs emphasis operating expenditure

Table A5: Comparing FFVs to LCVs in the civil society under different cost conditions

Civil society subsector	Respondent	When LCVs are costlier than FFVs					When LCVs are same cost as FFVs					When LCVs are cheaper than FFVs				
		LCV options					LCV options					LCV options				
		Biofuel vehicle	Electric vehicle	LPG vehicle	CNG vehicle	H2 vehicle	Biofuel vehicle	Electric vehicle	LPG vehicle	CNG vehicle	H2 vehicle	Biofuel vehicle	Electric vehicle	LPG vehicle	CNG vehicle	H2 vehicle
Educated	1	2	2	0	1	0	3	4	3	3	0	4	5	4	4	4
	2	1	1	1	2	0	2	2	2	4	2	5	3	3	5	3
	3	1	0	3	2	1	3	2	5	5	2	3	5	5	5	5
	4	2	2	2	3	0	3	3	3	5	3	5	4	4	5	4
	5	1	2	2	2	2	3	3	2	3	5	5	4	4	4	3
	6	0	2	1	0	0	3	3	3	2	1	4	3	4	4	4
	7	1	3	2	4	1	5	4	3	5	4	5	5	4	4	5
	8	0	0	1	2	0	3	4	3	4	3	4	4	5	5	3
	9	1	2	0	1	1	2	3	4	4	3	5	5	4	4	6
	10	0	2	1	2	1	4	3	2	3	2	5	5	4	4	4
	Avr	0.9	1.6	1.3	1.9	0.6	3.1	3.1	3	3.8	2.5	4.5	4.3	4.1	4.4	4.1
	%	18	32	26	38	12	62	62	60	76	50	90	86	82	88	82
Semi-educated	1	1	1	1	1	1	2	2	2	2	2	4	5	5	5	3
	2	2	1	0	0	1	2	2	2	2	2	3	3	3	3	3
	3	1	1	1	1	0	2	2	1	2	1	4	3	3	4	3
	4	2	0	1	1	0	2	2	1	2	2	4	5	5	5	4
	5	1	1	1	1	1	1	2	2	2	0	4	4	4	5	3
	6	0	0	0	1	0	1	2	1	2	1	4	4	3	5	4
	7	1	1	1	1	1	2	2	1	2	2	5	3	4	4	3
	8	0	0	0	1	1	2	2	2	2	0	4	4	4	3	3
	9	0	1	1	1	0	1	2	1	2	1	4	5	4	4	4
	10	1	1	1	1	0	2	2	1	2	2	5	5	4	5	4
	Avr	0.9	0.7	0.7	0.9	0.5	1.7	2	1.4	2	1.3	4.1	4.1	3.9	4.3	3.4
	%	18	14	14	18	10	34	40	28	40	26	82	82	78	86	68
Un-educated	1	0	1	1	1	1	2	2	3	3	2	5	5	5	5	4
	2	0	1	0	1	0	2	3	2	2	2	5	5	5	5	4
	3	0	1	0	1	0	2	2	1	1	1	4	4	4	5	4
	4	0	2	2	0	1	2	3	3	2	2	3	4	4	4	3
	5	1	2	2	1	0	3	3	3	2	1	4	4	4	4	3
	6	0	2	1	2	1	3	3	2	3	1	3	4	3	4	4
	7	1	3	2	0	1	3	4	3	2	2	4	5	4	4	2
	8	0	2	0	1	1	2	4	2	2	2	3	5	3	3	3
	9	0	2	2	1	1	2	3	3	2	2	4	4	4	4	3
	10	1	2	2	2	0	2	4	3	3	1	4	5	4	4	4
	Avr	0.3	1.8	1.2	1	0.6	2.3	3.1	2.5	2.2	1.6	3.9	4.5	4	4.2	3.4
	%	6	36	24	20	12	46	62	50	44	32	78	90	80	84	68
Avr %		**14**	**27**	**21**	**25**	**11**	**47**	**55**	**46**	**53**	**36**	**83**	**86**	**80**	**86**	**73**

Notes:

- Tendency of LCV acceptance scale: 0 – 5 (0 being impossible and 5 being very possible)
- Costs emphasis operating expenditure