# SUSTAINABLE FUTURE MOBILITY

by

Devendra Rajaram Gandhi, B.Tech., MBA, AMAeSI, PG-AIML, PD-RT

DISSERTATION

Presented to the Swiss School of Business and Management Geneva

In Partial Fulfilment

Of the Requirements

For the Degree

DOCTOR OF BUSINESS ADMINISTRATION

SWISS SCHOOL OF BUSINESS AND MANAGEMENT GENEVA

June, 2023

SUSTAINABLE FUTURE MOBILITY

by

Devendra Rajaram Gandhi

APPROVED BY

Jaka Vadnjal, PhD, Chair

Iva Buljubašić, PhD, Committee Member

Eduard Plavec, PhD, Committee Member

RECEIVED/APPROVED BY:

<Associate Dean’s Name, Degree>, Associate Dean

## Dedication

This dissertation is dedicated my family, parents, colleagues and friends who supported me throughout this long research work journey.

## Acknowledgements

I would like to acknowledge and whole heartily express my gratitude to those who supported me to complete research.

I thanks to my family, thanks for giving me support to complete this research.
I would like to sincerely thank to my mentor Dr. Eduard Plavec for your guidance, support and patience throughout the study.

Thanks to all who participated in the research survey and shared valuable feedback to take research forward.

Thanks to my office manager, head of department, complete management and all office friends to support me to complete my research work and provide the valuable input.

I am grateful to the support of my family, colleagues, friends, office management and all who supported directly or indirectly.

ABSTRACT

SUSTAINABLE FUTURE MOBILITY

Devendra Rajaram Gandhi

2023

Dissertation Chair: Jaka Vadnjal, PhD

The transformational changes are going on in the field of mobility. The major focus in the transformational changes is to decarbonise of the mobility. The various technologies are under implementation and some under exploratory phase to decarbonise the mobility. The sustainable mobility approaches are there to reduce or minimize the greenhouse gas emission in the mobility sector. The various megatrends are evolved as future mobility. The future mobility is around centralized motorized mobility. The future mobility trends are projected toward the sustainable mobility but as per the past studies mobility is unsustainable. There is need to do research in area of sustainable future mobility. So, this research is concentrated on the "sustainable future mobility" and identified scope beyond the decorbanisation mobility.

The individual mobility technology efforts are found to make future mobility sustainable. The sustainable mobility is not an individual effort but at central of other various sectors. The previous research and studies are found the need to integrate future mobility. But there is no detail research are available to integrate the sector or resources other than mobility in Indian context. There is limited research available to integrate the mobility technologies as intersectoral integration. The mobility is vast area in respect to country, region, continents, etc. So, to complete the study on time this research is focus on

India. This research is focus on current decorbanisation status of mobility in India, identifying the sector or resource which need to integrate for sustainable future mobility.

The research is done by designing the survey questions and feedback taken on same on scale of the 1 to 10. The sector for survey is selected considering the past research, direct connect to mobility ecosystem and common sectors. The survey has been taken by creating google form, direct interacting mobility sectors and other concern sector leader. The research results are indicated need to integrate the sectors or resource such as energy sector, human behavior, infrastructure, the commercial sector, government policies and schemes, technologies (digitalization, artificial intelligence) mobility as a service and the education sector. The important elements for economic model are identified in this research which important to implement the sustainable future mobility in India.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION

AV - autonomous vehicle

EV - electric vehicle

CV - connected vehicle

HEV – Hybrid electrical vehicle

BEV - battery electric vehicle

PHEV – plug in hybrid electrical vehicle

FCEV - Fuel cell electrical vehicle

CAV - connected vehicle, autonomous vehicles

SM - shared mobility

MaaS - mobility as a service Maas

OEMs – original equipment manufacture

ACES - autonomous, connected, electrical and share

CASE - connected, autonomous, shared and electrical

SAEV - shared, autonomous, electrical

MADE - mobility, autonomous driving, digitalization, Electrification etc.

GHG - greenhouse gas

UN – united nation

SDG - Sustainable Development Goals

UNECE - United Nations Economic Commission for Europe

TCO - Total cost of ownership

ICE – Internal combustion engine

CO – Carbon di-oxide

HC – hydrocarbon

NOx, - Nitrogen oxides

PM – particulate matters

US – united state

NDCs - Nationally determined contributions

NNEMMP - National Electric Mobility Mission Plan

CMPs - Comprehensive Mobility Plans

UK – United Kingdom

EU – European union

AI – artificial intelligence

AFC TCP – advance fuel cell technology collaboration program

WTW - Well-to-wheel

LCA – life cycle assessment

GREET -greenhouse gases, regulated emission and energy used in technology

NZE - net zero emission

COP26 – conference of parties 26th

GEF - Global Environment Facility

GEMP - Global Electric Mobility Program

IEA - International Energy Association

ICCT - International Council for Clean Transportation

kWh - kilowatt-hours

DC - direct current

IRENA – international renewable energy association

CCS - carbon capture and storage

ILUC - indirect land-use change

FAME - fatty acid and methyl esters

HDRD -Hydrogenation-derived renewable diesel

BECCS - biofuel with carbon capture storage

VKM – vehicle kilometer travel

PKM – per kilometer

FAV - fully automated vehicles.

SAE – society of automobile engineers

VES - Vehicle emissions standard

V2G - vehicle-to-grid

V2H -vehicle-to-home

GDP - gross domestic product

FAME - faster adoption and manufacturing of an electric vehicle

SDG - Sustainable Development Goals

IT – information technology

# CHAPTER I: INTRODUCTION

# FUTURE MOBILITY

## 1.1 Introduction

The mobility provides a purpose to a better quality of life to serves as a powerful symbol of freedom and progress. The mobility is allowing us to move whenever and however we want. Even it is enabling us to live, work and play in ways unimaginable just a century ago. The mobility is undergoing the transformational changes. This transformation is drive by global warming, 2 deg surface temperature reduction, emission, Paris agreement (Andrei et al., 2017). As per available publication data, the mobility industry is contributing to 27 – 30 % emission among all sectors.

The mobility is one of the pivotal sectors which have capacity and capability to drive sustainability change.

The various research and data are available on this area (WEF, 2021). The available research is concentrated on specific area and conclusion has been drawn accordingly. The various challenges are faces by mobility sectors and available research attempt to address by transportation solution, net-zero carbon emissions policies, alternate technologies and policy mechanisms etc. At present limited practical research data is available on the future mobility (Chakraborty, 2021).

The constrain referred here are like sustainability, change in customer behaviors, rapid introduction of surrounding technology, etc. The various themes are prepared to address this constraint and published as mobility disruption. But in this comprehensive approach is missing to make mobility suitable to meet long term sustainability goal.

As per available research data potential factors identified which are disrupting mobility industry drastically. The noteworthy transformation detail is offering lessons to leaders from all industries. The critical factors such as global competition, technological advances, autonomous vehicle (AV) (Threlfall, 2019), innovation and investment in electric vehicle (EV) are playing critical role. The numerous opportunities are showcased by well-established automakers, mobility start-ups by investor enthusiasm, strong auto sales, technological advances in vehicle connectivity, expanding sources of consumer data and potential new partnerships with tech companies (Fagnant, Kockelman and P Bansal, 2015).

The critical transition trend such as global emission, country wise regulation, technological innovations, demanding consumer expectation, increase traffic congestion in urban areas, speed of electrical vehicle adaption are defining next level of challenge to future mobility for revolutionary change. This area is the beginning of mobility sector shift with new opportunities and risks (Singh, 2015).

### 1.1.1 Future mobility megatrend in current market

The mobility transformation is driven by mega technologies disruption trends (Toshiba, 2019). The megatrends are alternative powertrain with electrification of vehicles (EVs), hybrid EV (HEV), Fuel cell EV (FCEV), connected vehicle, autonomous vehicles (CAVs) and shared mobility (mobility as a service Maas)). At present each above megatrend is impacting mobility sector independently and significantly disruption in ecosystem happening with this. As predicted in combination this megatrend can drive unprecedented change which yet to analyses in totality. The conventional vehicle OEMs are concern about this megatrend. The various actions plans are getting framed around this key transformation trend in different way (BloombergNEF, 2022).

Future mobility trends acronyms are mentioned by different research firm differently.

1. ACES - autonomous, connected, electrical and share
2. CASE - connected, autonomous, shared and electrical (TFM, 2019)
3. SAEV - shared, autonomous, electrical (Lutz and Philip, 2022)
4. MADE - mobility, autonomous driving, digitalization, Electrification etc.

The acronyms are summary of trends to use in various forum. Acronym's arrangement of individual trend is different, but megatrends common in each. The transformation in field of mobility is fueled by significant technologies-driven disruptive trends: electric vehicles (EVs) i.e., alternative powertrains, connected vehicle (CV) and autonomous vehicles (AVs) and share mobility (Maas – mass as a mobility).

### 1.1.2 The disrupting Future mobility - vehicle technology

The alternate powertrain (PHV, EV, FCEV), vehicle automation, connected vehicle, shared mobility are megatrends adaption is must for net zero commitment. The net zero commitment is holistic approach focusing on the tempting goals of 6 zero's; zero-emission, Zero-Energy, zero-congestion, zero accident, zero empty and zero cost (Frank, 2020). This net zero goal approach is navigating towards a new economy, sustainable ecology and more time efficient mobility (Rifkin, 2014). Along with other mentioned megatrend net zero is one of indirect efficient terminology to define future mobility efficiently. The megatrend acronyms are used to discuss future mobility conveniently in al various forum

As per mobility driving factors study, technology required for future mobility is new and nascent enough. The researchers are just navigating to catch stuffs and few stuff yet to catch to speed up for future mobility market growth. As per revied data, there is lot of uncertainties about rate of adaptions, time span to boost market, technology and business strategies of future mobility. Each mobility megatrend moving as per there space. But future mobility megatrend EV growth trajectory is driven by sustainability commitment (SLoCaT, 2018). So, visibility of EV penetrations is much clear than other megatrends. For this technology-innovation and business strategies have to be defined rightly.

There is intensive research on mobility powertrain technology and trend as net zero emission mobility. In this battery electric mobility is focus area and various actions in place. The various OEMs, government authority, public institute are working on mobility under net-zero emission initiative. By taking this reference few countries and OEM have announced plan to move for net zero emission vehicle to address the greenhouse gas (GHG) emission challenges (Murphy et al., 2021). Along with electric powertrain technology under net zero emission initiative, various research is going on share mobility, mobility as service, connected vehicle and autonomous vehicle. In net zero emission vehicle alternative powertrain vehicle like, HEV (hybrid electrical vehicle), BEV (battery electric vehicle) and FCEV (Fuel cell electrical vehicle) are major focus in research are for future mobility (Mariano and Mario, 2020).

The various mobility technologies, net zero emission initiative and other research has been discussed in various forum by country wise representation, research institutes, experts and consumers. The everyone is appreciating the working going to reduce emission and activities are supporting the climate change action plan. But limited alignment on sustainability point of view. The research and work available are in each domain with specific point to achieve emission reduction (Murphy et al., 2021).

### 1.1.3 Future mobility for Net zero emission

The consumers, government body, domain experts and researchers are appreciating the current level of mobility development and net-zero emission mobility initiative. But sustainability expert, mobility value chain expert, informed consumers have conflicting thought in acceptance of this technology for sustainability at this moment. Since the available research are covered individual point for sustainability but cross boundary connect is missing (UN habitat, 2021). This is the gap in current available research. This is important point to address for sustainability. In this research attempt to address this point. So, to achieve sustainability benefit complete value chain in integration is important (Matteo, 2022).

### 1.1.4 Sustainable mobility and global definitions

The sustainable mobility definition goes far beyond emission reducing. The mobility sector has potential to improve quality of the life and livelihoods of billions of people. However, at time of meeting people’s today’s needs, the sector must be ready to respond to future generations’ expectations. This is the essence of sustainable development. The sustainable mobility is characterized by either low or zero emissions. But sustainable mobility concept is goes beyond one step of this. The purpose is to re-organize the traffic in a major city or metropolitan region. So, that the ecological footprint is reduced to a minimize resources consumption than available or can be regenerated. The sustainable concept is to transform mobility from a ecology point of view. The emission reduction or zero emission is achieved by regenerating ecosystem (Bruno et al., 2021).

The various global definitions of sustainable mobility are as below.

1. Sustainability of mobility definition refer, the ability to meet society's need to move freely, communicate, gain access, trade and establish relationships without sacrificing essential human or ecological values, today or in the future.
2. UN has defined, the provision of services and infrastructure for the mobility of people and goods, advancing economic and social development to benefit todays and future generation. The manner with mobility to be accessible, affordable, safe, efficient and resilient with minimum emissions and environmental impact.
3. UN general high - level advisory group defined that transport is not an end but rather a means, allowing people to access for: education, jobs, social interaction, markets, goods and range of services contributing to healthy and fulfilled life's". (UNECE, 2021; 2022)

In literature no standard framework or definition found for a sustainable mobility. This concept was original principle component of  sustainable development which is brought to international attention by united nation report of the world commission in Environment and Development in 1987 (Brundtland, 1987). The sustainable development broad meaning defined is meeting the present needs without compromising the own need of future generations (Lane and Colin, 2013).

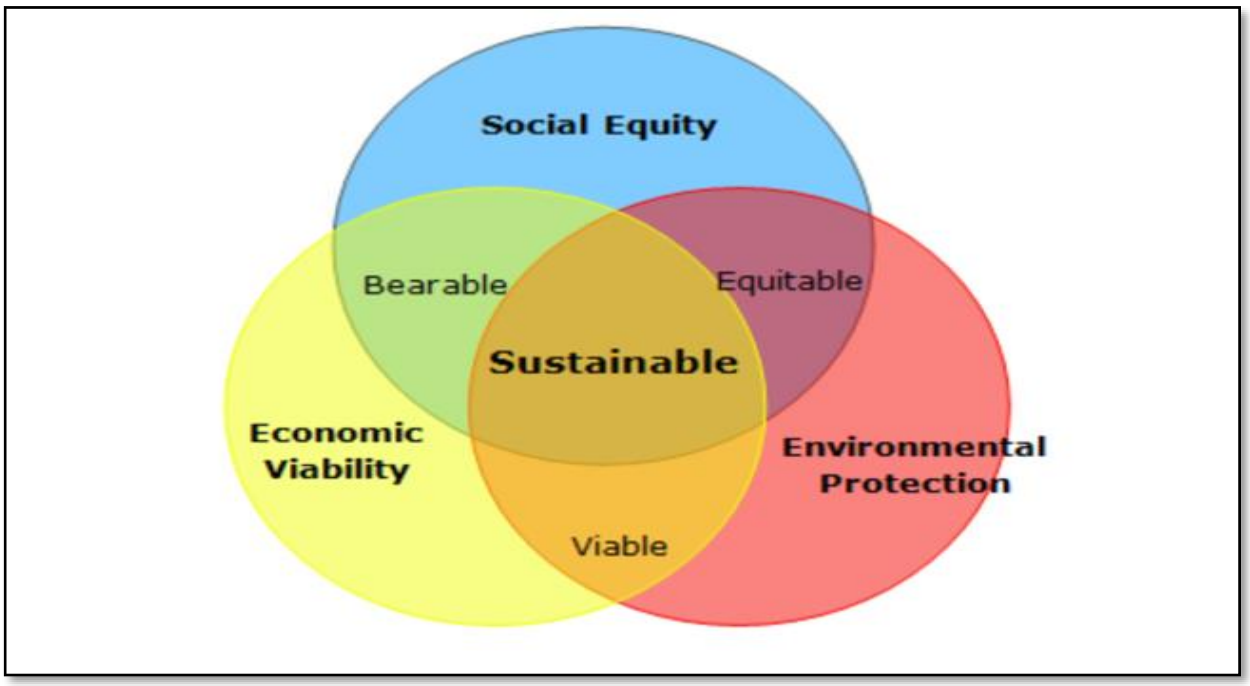
As per the international definition, it is important to integrate for sustainable mobility.  It is a big term and many definitions available. The core concept of this is to protect future while working on present issue. The example like, lack of parking spaces, traffic jams in urban area and accidents increasing with increase pollution and infrastructure.  The sustainable mobility concepts is to take care of this to reduce significantly or even avoid (Kuhlman and Farrington, 2010).

It is also referred as provision of infrastructure, services, technology and information to enable access to services, goods and participate in activities. It will help for development to ensures a safe and clean environment for everyone. Along with this it will help in enhancing economic and social development across countries. In general discussion sustainable mobility refers to any means of transportation that is 'green' and has low impact on the environment. The sustainability is also considered balancing of our current and future needs. The examples are walking, cycling, transit, carpooling, car sharing and green vehicles (Zankl, 2021).

### 1.1.5 Sustainability pillars

The various thought and principle are put in literatures. The one of sustainable mobility principles foundations made up of 3 pillars: economy, society and environment. These principles are also used in various forum as profit, people and planet. The below figure 1.1 suggests three pillars of sustainability where environmental protection, economic viability and social equity.

**Figure 1.1 Sustainable mobility definition (SWARCO, 2021)**



The Sustainable mobility can develop and ensures a safe environment for everyone (Figure 1.1). It will helps in enhancing economic and social development across the nations. The few sustainable individual initiatives are shifting from individual motorized transport towards public, avoiding motorized trips, reducing trip frequencies distances of all possible modes, active mobility, energy efficiency improvement, technology accessibility and safety of the transport system (SWARCO, 2021).

### 1.1.6 Sustainable Development Goals (SDGs)

The UN has sets up the 17 SDGs in that mobility have major role to play to eliminate poverty and fulfil sustainability target. The purpose is to provide equality, accessibility, paying special attention to populations those more vulnerable and geographic regions disconnected from social involvement. So, it is importance to create awareness among citizens for sustainable mobility. The governments must come forward to achieve this. The global road accident data have shown that almost 1.3 million individuals pass away annually due to traffic-related accidents. This is undoubtedly the most distressing fact globally.

**Figure 1.2 Importance of sustainable low carbon transportation system (SLOCAT, 2018)**

1.1.7 Sustainable future mobility development is impacted by

As per bigger perspective sustainable mobility (figure 1.2) has a significant and extensively benefits. This is advantageous for economic growth. The studies show that commercial activity and related profits significantly increase in regions that are blocked to motorized traffic and only accessible to pedestrians and bikes. The below are important benefit of sustainable mobility.

Healthy lifestyle

The public transport can be used reduce traffic congestions source of reduces greenhouse gas (GHG) emissions. Even reduced number of cars tripes and reduce GHG of cars on road. Due to these pollutants from the emissions from automobiles might reduce result reduction in a wide range of chronic illnesses.

Conservation of more land

The shorten distance between locations help for compact development and support sustainable transportation. The countryside and outskirts of cities with fewer roadways and paved areas compare to metropolitan centers will help to create room for parks, farms and other green areas. This will create less roads in rural regions to safeguarding the land and the wildlife.

Reduces congestion

The congestion naturally will reduce when individuals prefer public transportation over driving their private vehicles. The people who continue to use highways and city streets public transport reduce commuting times and driving stress. The benefit of this is to shorter journey times. The commuting workers can reach destination faster with trains. Since there is no stop, restart at traffic lights and crossings.

Safety is given preference

The public transport is 10 time safer per miles private car to bring in city. As benefit of this commuters can lower their collision risk by more than 90% due to public transportation. At present this is the greatest cause of death for 5- 29-year-old young and children’s and count for approximately 1.35 million deaths annually. The safe mobility is a key of sustainable future mobility.

Saves energy

The oil and gas are major non-renewable energy sources used to in transportation sector to produce energy which required as per type of transportation. The road transportation is responsible for 90 % whereas rail and water account for 10 % environmentally hazardous pollutants. The move toward renewable energy sources wind, solar energy etc. can resolve this problem at extent. The overall congestion reduction can result in overall energy savings. The use of public transportation, bicycling and walking save energy.

To create More job opportunities

The sustainable transportation will be more productive if transportation is economical, ecofriendly and effective while freeing up resources for other required uses. For development of sustainable future mobility is very equitable the abilities of innovators, designers, construction professionals, drivers, maintenance workers, safety officers and many concern people with a wide range of skills. The development of necessary infrastructure to support public transportation, alternative fuel technological vehicle and new modes of transportation will create employment opportunities.

Reduces pollution and GHG emissions

The personal vehicle is primary source of pollution. The public transport buses and trains contribute a smaller quantity of emissions but making them more ecofriendly is important than private vehicles.

Helps in saving money

The public transportation can save money which required for costlier personal vehicle purchase cost, maintenance cost, fuel prices etc. Public transport is more affordable for weaker sections of the society. Even adoption of electric vehicles will come with a lot of low interest loans, benefits in taxes, subsidies etc. In the early phases of sustainable transportation development is costlier to construct roads, set up infrastructure networks and for buying vehicle. The quantification of return on investment in terms of sustainable is and saving to people is very high

### 1.1.8 UNECE to address SDG implementation priorities by Nexun project

The sustainable mobility is ideally eco-friendly, economic, social, safe, affordable and efficient. The UNECE has multi-sectoral sustainable development goal. In the mobility this is one of the thrust points and due to this important nexus 4 are defined. This project will allow to address sustainable development goals (SDGs) implementation in an integrated manner by the interlinked character. This will adopt a new way of which cut across sectoral boundaries. The nexus projects are,

- Sustainable use of natural resources
- Sustainable and smart cities
- Sustainable mobility and smart connectivity
- Measuring and monitoring progress towards the SDGs.

The UNECE inter-divisional and cross-sectoral experts has taken in-depth analysis of each of these areas. As per this, they have identified the current and future challenges, ways and means to address them. They are assisting member state to design and implemented integrated policies in these areas (UNECE, 2021).

### 1.1.9 Total cost of ownership (TCO) for future mobility

The world population and incomes are increasing. Due to this mobility is reaching to hundreds of millions more consumers. Along with few points are remains uncertain like clear mobility evolution roadmap, changes required in mobility to addressing public policy requirements, reducing of city congestion and action plan to meet global climate challenge (Adam et al., 2018). The much intensive further analysis is required on drivers (i.e., technology, economics, policy and consumer behavior/preference) which potentially impacts and interact with one another.

The current battery electric vehicle trend has economic and technological challenge w.r.t. ICEs vehicle. The challenge is battery cost and range of vehicle even though there are subsidies are available in some countries. In BEV total cost of ownership analysis is sensitive factors including ICE fuel prices, electricity price, maintenance costs fuel economy of ICEs, vehicle life, battery life, battery size, subsidies rate, country wise taxes and insurance. The BEV are more favorable in some countries where electricity price is less compared to ICEs vehicle fuel prices (Bentley et al., 2019).

The challenge face by high mileage drive is high charging cost at public charging station compare home charging cost.  Along with total cost of ownership other important multiple factors are there to determine consumer decisions regarding BEV purchases. As per current available infrastructure ICEs vehicle will be remain the least expensive to manufacture for many years to come. The emission and fuel economy regulations are increasing manufacturing costs for ICE vehicles.

The ICE vehicle fuel that complies with pollutant (CO, HC, NOx and PM) criteria of regulations are expected to remain less than the upfront cost of comparable BEVs and FCEVs BY and beyond 2030. As per one dimensional cost analysis current price premium for BEVs and FCEVs over ICEVs will reduce as battery production volumes and efficiency increase. But as per the available analysis manufacturing costs for BEVs are expected to remain higher than for ICEVs well beyond 2030. But as per of total cost consideration lower per-mile costs for fuel (electricity) and lower maintenance costs can attracted by BEVs w.r.t. ICEs vehicle to reach parity (Kishimoto, Paltsev and Karplus, 2015).

The TCO is driven by many factors, including subsidies, fuel economy, gasoline price, electricity price and battery costs—all of which are subject to uncertainty. As per present analysis BEVs cannot compete directly with ICEVs for TCO without the support of subsidies and regulations, except in a few countries, such as Norway, where gasoline prices higher than electricity prices. As per analysis battery costs of BEV decline will help to reach TCO parity even without government subsidies in additional countries where gasoline prices are high compared to electricity. But this estimate is sensitive to various uncertainties which varying from country to country and region to region. The BEV price reduction and a financially reasonable discount rate can bring TCO but consumer behavior toward ICEVs will continue to be viewed as the more affordable by 2030 and beyond. The review has illustrated that only financial parity will not bring faster and wide adoption of sustainable alternate powertrain vehicle.

### 1.1.10 Sustainable Mobility

The ‘sustainable mobility’ concept coined in discussion in 1992. It is 1$^{st}$ published in the EU green paper on the “Transport impact on the environment”. As per sustainable mobility understanding and interpretation of the societies regarding “sustainable mobility” evaluation had reviewed and reflected. There are various transitions in the mobility area. These transitions are grouped in to 4 generations. As per various transition in mobility up to the from this review we assert that the mainstream understanding and interpretation of sustainable mobility can be grouped into four generations of studies.

1. 1992 – 1993 first generation of studies – this is techno-centric and focused limiting transport’s negative environmental impacts by improving current technology and new technology. 2. studies (1993 – 2000, 2000 – 2010 and 2010 – 2018 respectively) – 2$^{nd}$, 3$^{rd}$ and 4$^{th}$ generations of – in this mobility sector acknowledged the limitations ongoing efforts to achieve sustainability and well come door for a more diverse alternative.

In this above generation the evaluation of sustainable mobility has below dimensions,

i. Research and policies
ii. Transport impact and categories
iii. Scientific disciplines
iv. Methodological approach
v. Research question

The subsequent elevation of mobility is in process toward next futuristic the mobility. But still we have not achieved a sustainable mobility system. So, to reach sustainable mobility the holistic picture to be capture. The detail review, various literature and study illustrate that the current mobility is unsustainable. Along with that mobility gradually become more interdisciplinary in nature. These reflecting the interrelatedness of mobility with all other aspects of society. We will achieve sustainable mobility in future by elevating a mobility into holistic way in the society. So, we required to set much more bold new narrative needed now than past since ever (Banister, Erling and Gilpin, 2019).

#### 1.1.11 Sustainable mobility in Indian ecosystem

The world population is increasing and estimated to grow by 65 million annually. Along with population the urbanization rapidly increasing. As part of action plan several countries like US, China, South Korea and Europe adopted EV to reduce emission increasing along with urbanization. India has also projected EV market growth up to $ 206 billion by 2030. The estimated investment in country to meet this is over $180 billion for vehicle production and charging infrastructure. In this scenario the multiple stakeholders like customer, government (local, state and central), technology provider, concern manufacturing industry are going to play vital role. The success of this predominantly depends on the cities and going to play important role. So, Indian cities have crucial role to play for NDCs (Nationally determined contributions). The one of the important initiatives is EV vehicle introduction. But still the traction for EV transition has several challenges as mentioned below (LCST, 2020).

**i. Charging infrastructure**

As per data in India by 2016 less than 500 EV charging stations across major cities Delhi, Mumbai, Bengaluru and Kolkata. By July 2020, this charging station increased to 993. For EV success the right placement of numbers of charging station along with enough number of stations are important factor. As per 2030 vehicle growth estimation, 30 % EV penetration is expected to meet emission level. As per this projection Delhi need 300000 charging station. The projected investment for this charging infrastructure is around US $1.5 billion. The additionally high-speed chargers and the expansion of power grids can prevent this transition (IEA, 2020; 2021; 2022).

**ii. E-Waste management**

EV waste is one of the hazardous wastes and presently most of the e-waste gets dumped in landfills. This is a hazardous way of dealing with such refuse. So, to handle this EV waste including batteries end of life cycle is required a technological expansion in EV recycling industry. The current policy changes are required to support technological changes required for EV recycling and waste management (IEA, 2021).

**iii. EV30@30 Campaign**

The government of India has declared EV30@30 Campaign as clean energy ministerial initiative. The aim of initiative is to achieve EV sales 30% by 2030. This includes closely 80% of 2-wheeler, 80% 3-wheeler, 70% commercial cars, 40% of buses and 30% of private cars to electrified by 2030. India's participation in EV30@30 campaign is link to climate commitment efforts. The campaign is also focusing on the required charging infrastructure and sufficient electrical power for deployed electrical vehicles (IEA, 2020; 2021).

**iv. National Electric Mobility Mission Plan (NEMMP) 2020**

In 2020 government of India has outlined NEMMP (National electrical mobility mission plan). It has included the roadmap for manufacturing of EVs and faster adoption in India. The Department of Heavy Industry has created FAME India in 2015 for manufacturing electrical vehicle in India. The aim was to promote development, substantial growth of electric and hybrid vehicle technologies (IEA, 2021).

**v. Comprehensive Mobility Plans (CMPs)**

The many cities in India have prepared comprehensive mobility plans independently or with central government of India assistance. The cities area crucial part for the sustainable mobility journey. Since vehicle density in cities per 1000 people and land available is less per 1000 vehicle.

The policies ultimate implementation in cities is happening at the local government level. The important cities like Mumbai and Pune in have prepared CMPs unassisted plan. The states like Karnataka and Punjab have prepared CMPs with the central government of India support (IEA 2021).

**vi. Paris climate agreement**

India’s efforts toward electric vehicles partially link with commitment toward Paris climate agreement to reduce emission (greenhouse gases), transition toward clean energy and contribute to mitigate climate change effects. India had pledged to increase non fossil fuel-based energy resources to 40% of installed capacity and committed to reduce emission intensity from 33% to 35% by 2030 (IEA, 2021).

**vii. The ease of doing business**

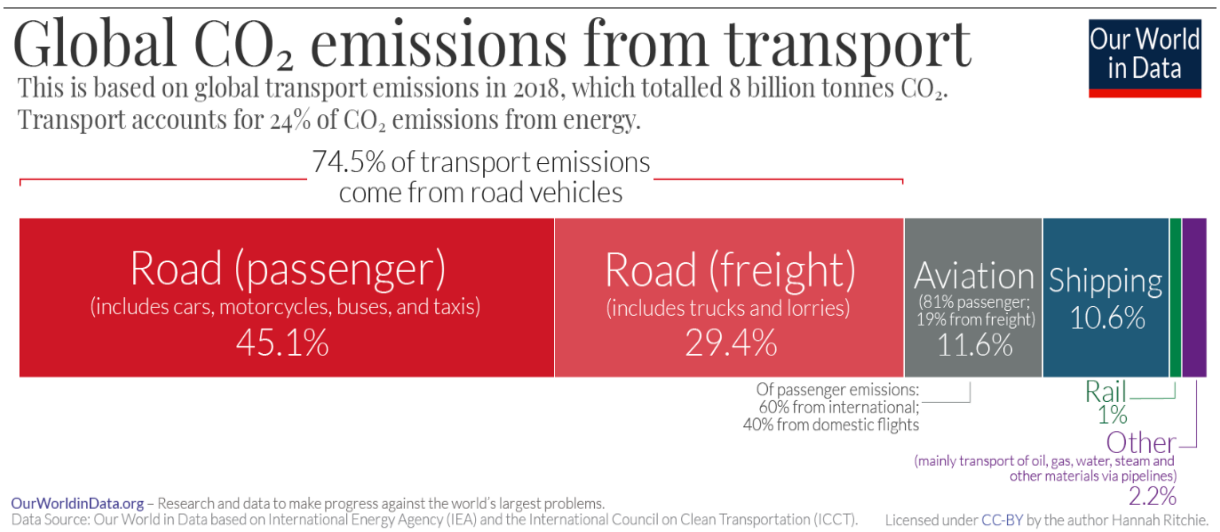
The India’s e-mobility can catalyze consumer product innovation, modernize manufacturing industry and digital innovation. The e-mobility manufacturing industry required to keep pace because there is high level of expectation and anticipation of demand. The priority areas of innovations have been outline based on the expectation and demand like lithium-ion batteries, drivers, motors and ultracapacitors. The government India has rolled out (PLI) production linked incentive scheme in 2021. The aim is to incentivize the domestic production of e-mobility product such as batteries (advanced chemistry cell) and reduce import dependency. The battery is one of the important parts but along with batteries chargers, grid stability and stable power supply will also increase. The e-mobility will have an impact on various concern sectors of the market. The sector such as energy storage, electric component manufacturing, ancillary automobile industry, electricity supply infrastructure, every industry etc. will be benefits from e-mobility. The identified market potential in India for electric vehicles is immense. This potential can be tapped easily in India by right policies and support for all concern sectors (IEA, 2021).

### 1.2 Research Problem

The mobility sector transformation is recognized by everyone. This transformation is drive by global warming, 2 deg surface temperature reduction, emission, Paris agreement and other sustainable initiatives. As per various data publication, the mobility industry contributing to 24 % emission among all sectors (Table 1.1). The majority of vehicle OEM has started working toward for net zero emission vehicle by using alternate powertrain, share mobility, mobility as service, connected vehicle and autonomous vehicle. The end consumers as well as all countries have convinced to go for future mobility. The major introduction is net zero emission vehicle technology. Where tailpipe reduction work is appreciated to reduce greenhouse gas emission (Matthew, Nicholas and Fitzgerald, 2021).

The various technology, innovation and business strategies are evolving day by day in this area of future mobility. Sustainability is not only related to reduction of tailpipe emission. But this is broad term to reduce emission produce by complete concern value chain.

**Table 1.1 Emission from various transportation (WEF, 2021)**




At present complete integrated approach is not observed to achieve sustainable (UNECE 2021). Sustainable mobility defined by United Nations, the provision of services and infrastructure for the mobility of people and goods— advancing economic and social development to benefit todays and future generations—in a manner that is efficient, safe, accessible, affordable and resilient, while minimizing emissions and environmental impact.

The current future mobility research majorly focuses on reduction in tailpipe greenhouse gas (GHG). But sustainable mobility goes beyond reducing GHG emission. This is the necessity of sustainable development which is not covered in totality in current available research. Even undressed point in current research is, how to build sustainable mobility. The definitions of sustainable mobility are prepared by global organizations. So here referring common point from those definitions (IEA, 2016).

In summary, there is a need for a better understanding of sustainable mobility for future and need to integrate technology, fuel, government and consumers ensure sustainable future mobility. So, vehicles are become cleaner and quieter over time. But transport still produces too many emissions in entire value chain. The resource consumption and land use especially roads and parking's are continuously adding negative impact on the environment. The greatest challenge for sustainable mobility is to keep healthy balance between resource consumption by mobility users and regenerative capacity of the ecosystem. The comprehensive strategy is needed to find, realize and must master the following four challenges at its core (Knupfer et al., 2017).

Presently Methods adopted to implement sustainable mobility

- Use of public transport – The individuals are trying to limit use of their own cars and public transportation where possible. In big cities, this also help to reduce traffic and its associated pollution.
- Walking – In addition to sustainability, walking improves healthy aging, reduces stress, increases attention and does a lot more.
- Electric vehicles (EV) – It replaces fossil fuels and uses electricity as a power source. The input energy renewable sources like solar, wind energy etc. are important to strengthen sustainability with (EV). EV are not only eco-friendly to reduce emissions and they are economical too.

- Cycling for shorter transportation – this is eco-friendly, very practical to use and help for good health. This can be used for short distances and significant save amount of fuel.
- Railways for transportation – this is preferable choice for daily commuter. Because it produces low gas greenhouse emissions per passenger and this is most effective.
- Smart driving – The driving patten or habit to maintain vehicle posted limit without braking or acceleration is also effective way to reduce emission and fuel consumption too.
- Use of digital technologies – improving transportation efficiency and lowering pollution by digital technology and intelligent traffic management are made important initiative. The connected vehicle technology help user to connect through digital mode, encourage environmentally friendly travel decisions, enable multimodal travel decision, increase public transport access, reduce congestion and control fuel or energy use.
- Sharing of vehicles – this concept has potential to reduce both emissions and traffic. The user can avoid use on own vehicle and avoid having owned vehicles sit idle for most of the day by sharing different ways of transportation (scooters, cars and e-bikes). This helps to make more free space in the parking areas.

Sustainable Mobility goals and opportunities

sustainable mobility concepts promote the following goals and opportunities among others:

- Reduction in traffic jams condition
- Increase safety by reducing number of accidents
- Avoid or limit individual car entries
- waiting times reduction at traffic signals
- Green waves initiative and increase green zone
- Greenhouse gas emission and particulate matter reduction
- Avoid repetitive braking and acceleration - stop-and-go traffic condition
- Accessible or easier parking space
- More attractive public transport services

- Effective logistic trip
- Reduction in noise and sound levels

Sustainable mobility is not simply ticked off with the implementation of a single measure but requires a mix of measures.

Important core ideas around sustainable mobility

- As per current situation, impossible to organize traffic completely without emissions. Even though there is lot of sustainability methods are adopted
- There is major focus on vehicles and drivetrain technology with respect to other focus area
- At present there is no economic incentives for behavioural change. But this are essential for sustainable mobility
- The sustainable concept at present at regulation and policy level. But for successful, sustainable required acceptance of the population too
- At present mobility is a key prerequisite to participation in our society this concept change is important
- As per this sustainable mobility will not be 100% achieved until resources used to produce energy are renewable and the ecosystem regenerate around it

At present various initiatives are in place to drive sustainable mobility. The individual method mentioned above and other working. The various global level organization and individual countries, states, municipal corporation working toward sustainable mobility. The various individual research is available. But the one common points found in majority of report and research that sustainable mobility will not individual method or technology implementation goal.

The sustainable mobility can be achieved by compressive approach as well as by integrated approach. But at present there is not clear research available which sector integration required, the way to integrate, intersection point of each method or technology required. As per various literature the integrated or comprehensive approach are even required with same sector. But very limited research is available on this. Even though there very mix level of data available on this point. So, this is important to do intensive research on integrated approach, need to this to achieve sustainability. The integrated or comprehensive approach is very broad term. So, moving forward in need to align the research in step manner. In India the FSSI has done extensive research on individual technology on sustainable mobility. As per this research as well to implement to take it forward sustainable mobility integrated approach is important. But there is not clarity on what is to be integrate, which sector, or etc. (FICCI, 2021)

Specifically, following research questions need to be address:

1. What is sustainable mobility beyond GHG (greenhouse gas) emission reduction?
2. What is current level of research in integrated sustainable future mobility?
3. What are to be integrate for future sustainable mobility?
4. Why to be integrated to achieve future sustainable mobility?
5. How to integrate to achieve future sustainable mobility?

How integrated mobility create sustainable future mobility and help to address the emission challenge, build confidence in consumer and deliver economic output as per common sustainability definition?

### 1.3 Purpose of Research

As per recent research found that the current mobility is unsustainable. As pet study the interdisciplinary sector integration is required. But there is not any specific guideline or framework available for this. So, purpose here to study the Integrated approach requirement for sustainable future mobility. The objective of research is study past research done on same subject and understand suggested future work and potential gap. This research will help to provide a comprehensive review of literature and industry practices.

The long-term goal of research is to develop a framework for sustainable future mobility. The purpose of this research to outline a conceptual framework for sustainable future which

Particularly this study has following sub-objectives,

1. To provide a compressing review decide source to integrate for sustainability
2. To economic framework to integrate technology, fuel/energy, government infrastructure and consumer

The long-term goal of the research is to develop integrated approach to develop sustainable future mobility (Matthew, Nicholas and Fitzgerald, 2021). The sustainable mobility refer here is intersection of vehicle, energy, infrastructure and consumer. Since for sustainable mobility there is no single remedy. The factors involved to be addressed and actors already developing solutions need to work together. The integrated future mobility is to integrate or connect mobility elements to each other in such way success that all parts to be addresses whole. The result of this study will be valuable to the society, consumers, mobility industry practitioners, other related industry practitioner, policy maker (government / public) as well as related base for future researcher to develop better solution and tools future mobility.

As per various review and multiple study, the conclusion drawn is for sustainable future mobility the integrated or comprehensive approach is required. The integrated or comprehensive approach is very broad term. The mobility is cutting across all sectors. So, defining the integrated approach for sustainable mobility is required to understand concern each cross-sector point to develop sustainable mobility. The individual mobility solutions are working very well. But as per various study complete system level details are not justifying sustainability.

The noteworthy transformation detail is offering lessons to leaders from all industries. The critical factors such as global competition, technological advances, autonomous vehicle (AV) (Thomas and Threlfall, 2019), innovation and investment in electric vehicle (EV) are playing critical role. The numerous opportunities are showcased by well-established automakers, mobility start-ups by investor enthusiasm, strong auto sales, technological advances in vehicle connectivity, expanding sources of consumer data and potential new partnerships with tech companies (Fagnant, Kockelman and P Bansal, 2015). The critical transition trend such as global emission, country wise regulation, technological innovations, demanding consumer expectation, increase traffic congestion in urban areas, speed of electrical vehicle adaption are defining next level of challenge to future mobility for revolutionary change. This area is the beginning of mobility sector shift with new opportunities and risks (Singh, 2015).

### 1.4 Significance of the Study

This research thesis contributes to research literature for future and help in practice by following manner.

- It will provide a comprehensive literature to industries to understand current practices and outline a concept of sustainable future mobility.
- It will give framework to identify, classify, model and address mobility challenges to meet “sustainable future mobility”
- It will give major comprehensive framework to integrate technology, fuel/energy, government infrastructure and consumer
- Conduct compressive study of current “sustainable future mobility”, fundamentals and contribution factors
- Understand past development in field of “sustainable mobility” and shift to concept of “sustainable future mobility”

- This will help to understand the various sector which influencing the mobility sector and important to do comprehensive study of this sector. So, the interdisciplinary sector role can be understood to take future decision
- This research will help to identify the priority to go for "sustainable future mobility" which useful to industry leader, government authority, social organization to align activities
- This will research will help for environmentalist, city planner, social actors to re-think at time of going for new mobility decision. The city planner can take the input at time of the planning new city. So, from day one the "sustainable future mobility" input can be considered.
- This research will help for theoretical and practical input at time of deciding new regulatory framework
- This will attract interdisciplinary attention to boost mobility sector business
- This research has studied interdisciplinary sector and influence on mobility to make "sustainable future mobility". So, possibility to create new business opportunity which lucrative than current opportunities
- The result of this study will be valuable to the society, consumers, mobility industry practitioners, other related industry practitioner, policy maker (government / public) as well as related base for future researcher to develop better solution and tools future mobility.

This research will help to contribute future research and practice in below manner.

Develop integrated approach in long term manner for sustainable future mobility where intersection of vehicle, energy, infrastructure and consumer is important. Since sustainable mobility there is no single remedy. This will help to address the factors involved and actors already developing solutions to work together. The sustainable future mobility will help to integrate or connect mobility elements to each other to address mobility as whole for success.

### 1.5 Research Purpose and Questions

For "sustainable future mobility" is not individual mobility sector efforts but combine efforts of mobility sector as well as other interdisciplinary sectors. The purpose of this research,

1. to study current level of interdisciplinary sector integration with mobility sector to make future mobility sustainable
2. the importance of interdisciplinary sector
3. the way to integrate interdisciplinary sectors
4. the two way combine efforts are required.
5. to make future mobility will not succeed. In this research will study current level of engagement of interdisciplinary sector in Indian and awareness of the Indian consumers, mobility experts, government policy makers, vehicle manufactures to make "sustainable future mobility".

At present there is major focus on decarbonization, net-zero mobility are the important initiative in India.

So, this research will help to understand importance of other interdisciplinary sector along with mobility initiative to make future mobility in India as "sustainable future mobility." This to create framework for "sustainable future mobility. Since this is important long-term priority to make environment friendly, safe, accessible, economical mobility. This will create business opportunity by maintaining "Sustainable future mobility" purpose. This business proposal will have higher business and benefit potential. Since this is priority to everyone.

Research question

Answer of question on scale of - answered on scale of 1 to 10. (1 - strongly disagree 5 - neutral to 10 strongly agree),

1. The decorbanisation intiative will help to develop Sustainable future mobility
2. The ongoing efforts in mobility sector will help to develop sustainable future mobility
3. Quality of the life will improve with implimentation of sustainable future mobility
4. Cost of living will increase by adaption of sustainable mobility

5. Lower total cost of ownership and increase affortability of mobility will help for faster sustainable mobility In india
6. Sustainable future mobility success in india required contribution from other sector than transportion sector (alternate fuel technology vehicle like autonomous and connected vehicle), if yes respond on below.
   i. Energy sector
   ii. Human behaviour
   iii. Goverment policies and schemes
   iv. Mobility as a service (Public transportation, shared mobility, on demand sevice, rental)
   v. Commercial (Banking, Economic, finance and Insurance)
   vi. New technology – ditigalisation, Artifical intelligence,
   vii. Infrastruture and urbanisation development
   viii. Educational sector
   ix. All above sector together
7. The current mobility developement ( alternate fuel vehicle, share mobility, connected car, autonomous vehicle ) efforts are enough to develop sustainable future mobility
8. In indian context, for sustainable mobility required,
   i. faster intrducton and implimention of new technology like clean energy, battery electrical vehicle, hydrogen vehicle
   ii. instrastucture development for electrical and hydrogen vehicle
   iii. by current mobility efficiency improvement and parallel introduction of new technology in phase wise manner with time bond target
   iv. behaviral change toward mobility adaptibility and usage
   v. economical accesibility and affortability for mobility

vi. customisation of all mobility within metro, urban, rural and connection to this 3

vii. by right compressive implimention of all above

9. Scope of sustainability is envirovment friendly, safer, faster, reliable, socially desirable and cost efficient
10. Developing sustainable mobility will help to boost social and economical developemnt

# CHAPTER II:

# REVIEW OF LITERATURE

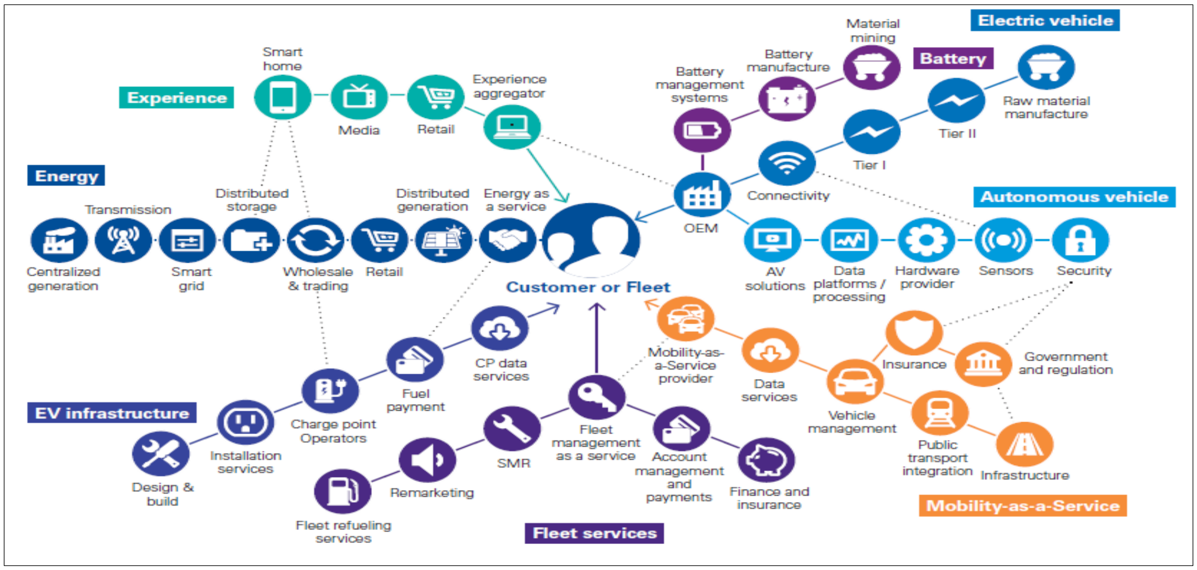
## 2.1 Introduction

The mobility is experiencing one of the most transformational change due to technology, economic, social and consumer behavioral shifts. The fundamental changes are happening in the way people and products moving. The frequent projected megatrend is CASE (connected, autonomous, shared electric vehicle) discussed at various platform. The trend such as sustainability, emerging technology, innovation, emerging start-up are playing important role to switch in future mobility. In this disruption era new mobility markets are emerging, some converging, few are disappearing entirely (KPMG, 2019). The adoption of technology trends, consumer behaviors and investments trend are fundamentally changing mobility businesses.

The mobility sector winners are likely those, who collectively understand change impact, adapt agility for change, invest in right emerging opportunity, aligned for right partnership, fucus on promising technology, look for innovation and foster new business strategies. As per legacy data value chain mapping changes in mobility industry was linear so far (KPMG, 2019).  But as per present mobility shift and future mobility scenario there will be exponential changes moving forward in mobility sector. This expansional changes will impact on concern sectors and ecosystem The various sectors are converging and eager to seize revenue opportunities. In future mobility consumer is at center point and complex interconnected web of value chains evolving around it (Figure 2.1).

The mobility is moving very fast from individual disconnected ecosystem to the interconnected ecosystem. The new entrants are to taking a share in mobility sector with unprecedented levels of partnership and collaboration. The users are looking for future mobility technology as purposeful solution to make mobility Cleaner, safer and more efficient.

**Figure 2.1 Future mobility interconnected network themes (KPMG, 2019)**




This purpose is supported by below consolidated data published by Statista publication.

i. 30% global greenhouse gas emission accounted by transportation sector

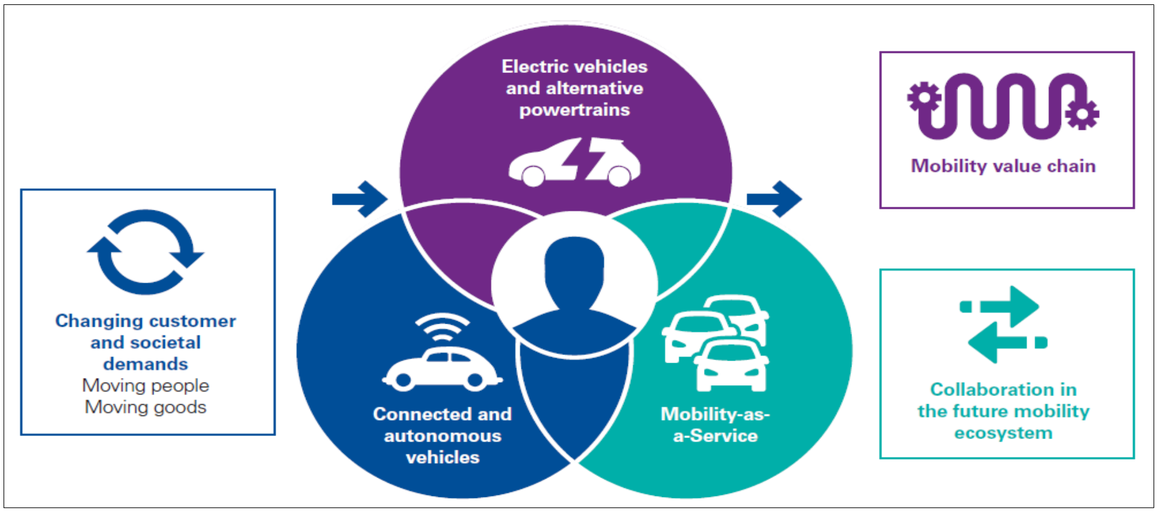
ii. air pollution causes around 4 lakh premature deaths every year

iii. road traffic crashes leading of death for children

Young adult aged 5 to 29 and average commuter spend time every year in traffic congestion e.g., in Paris avg. 165 hours in traffic (Statista, 2022).

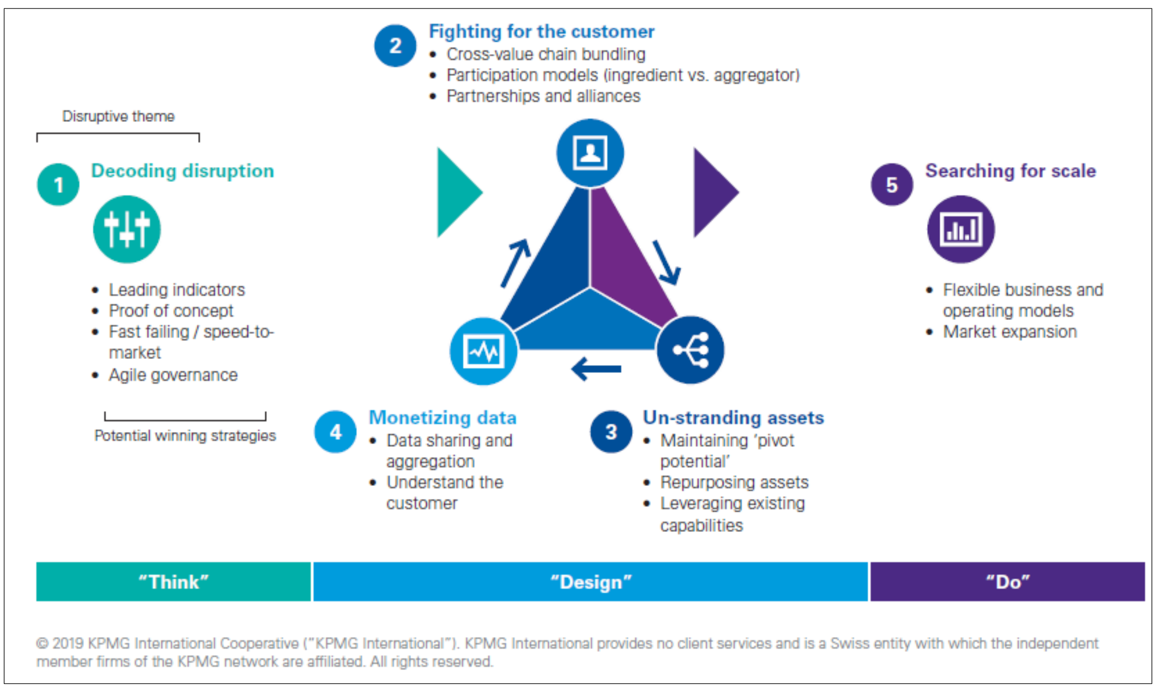
A preliminary review shows that there is intense focused on understanding mobility megatrend as per technological evolvement. The technology is evolving considering need of electrical vehicle, autonomous vehicle, regulation, connected car and shared car constraints (Foresight, 2019). But there is limited comprehensive focus to integrate technologies together. As example many companies are pushing electrification of an automobile vehicle, autonomous vehicle, shared car independently. The proper integration of common factor of this technology will help to make future mobility sustainable (Figure 2.2). The major automobile giants are declared not to invest in internal combustion engine-based vehicle model development due to stringent emission norms, fuel price economy.

Figure 2.2 Future mobility cross sector megatrend (KPMG, 2019)




There are various methods are applied by this OEM to deal with constraints and knowledge-based systems to boost technological innovation around.

**Figure 2.3 Future disruption themes (KPMG, 2019)**




The constrain referred here are like sustainability, change in customer behaviors, rapid introduction of surrounding technology, etc. The various themes (figure 2.3.) are prepared to address this constraint and published as mobility disruption. But in this comprehensive approach is missing to make mobility suitable to meet long term sustainability goal. As per available research data potential factors identified which are disrupting mobility industry drastically. The noteworthy transformation detail is offering lessons to leaders from all industries. The critical factors such as global competition, technological advances, autonomous vehicle (AV) (Thomas and Threlfall, 2019), innovation and investment in electric vehicle (EV) are playing critical role. The numerous opportunities are showcased by well-established automakers, mobility start-ups by investor enthusiasm, strong auto sales, technological advances in vehicle connectivity, expanding sources of consumer data and potential new partnerships with tech companies (Fagnant, Kockelman and P Bansal, 2015).

The critical transition trend such as global emission, country wise regulation, technological innovations, demanding consumer expectation, increase traffic congestion in urban areas, speed of electrical vehicle adaption are defining next level of challenge to future mobility for revolutionary change. This area is the beginning of mobility sector shift with new opportunities and risks (Singh, 2015).

Mobility as service (MaaS) (Thomas and Threlfall, 2017) is one of the megatrends evolving very fast to transport people, goods from one place other. The technology perspective of this is getting redefine and callout by various technologies trend. This are creating different thoughts for the ownership of vehicle. The various concept and technologies are tabled in literature as road map (NAFTA, 2017). This are opening door for new technology player coming to command by software platform. The discussion summary is that technology trend evolving and technology players already investing to make future mobility. So, to shape up future mobility as a sustainable mobility the technology-innovation and business strategies research is going to play pivotal role (Thomas and Threlfall, 2019). The future mobility megatrend and related adoption with consumer attitude, policy, demographic and country.

The personal mobility is one the centre point of growth. There are few data available mentioning exceptions for same. The various factors interaction and contribution has been studied to understand consumer inclination toward personal mobility. These various survey and study indicated that demand for personal mobility is get boost along with population and wealth growth. The major contributing factor studied are per kilometre travel or average fuel economy, demography, motor policies, geopolitical scenario, individual income, population (density and total) and consumer attitude. The conventional powertrain and electric vehicle (EV) growth trajectory analysis indicated that, there is boos for EV as personal mobility (Rieck, Ebbers and Boonstra, 2017). The China EV adaption policy enforcement by government has significantly impacted % growth positively w.r.t. rest of world. If such policy enforcement restriction in Chinas 64 city, may reduce 10% vehicle ownership by 2030 (*NAFTA*, 2017).

In China vehicle ownership reduction in city is driven basically by concern of air quality and not future climate change point of view (Dibbert, Schneider and Krzyzanowski, 2016). This policy promoted in China is related to vehicle in Chinese cities. There is not any indication at present on adaption of such policies in all cities in China (Kishimoto, 2018). But scenario analysis indicated that other large cities (e.g., Beijing, Shangai and other large city) may experience air pollution challenge in absence of the vehicle ownership reduction (Chun, Moody and Zhao, 2019).

The mobility ownership survey in different counties indicate attitudes toward mobility ownership differ across people and places. The vehicle pride is highest in majority continent of the people. The US vehicle ownership pride survey has indicated that people wanted to move away vehicle ownership. As per socio-economic urbanisation analysis, new generations requirements for vehicle travel and personal car travel are equivalent to past generations (Icek 2018). The attitudes toward personal mobility study across countries found that car pride is generally higher in developing countries. The trend in developing countries shows wealthy, the growing of the middle-class population is moving toward higher vehicle ownership pride, provided no policies constrained. The U.S. is one of the exceptions among developed countries toward mobility attitude (Rieck and Raak, 2014).

## 2.2 Mobility related challenges and shaping

The overall response to regulation, safety, net zero policy, attitude toward ownership of vehicle, urbanization, traffic congestion, technology-innovation and related business strategies for mobility is changing day by day (Machielsen, Rieck, and Duin, 2017). The consumer expectation, luxury inclination, easiness of travel, technologies, services, stringent regulation and policies toward mobility has evolved over decades. As per future mobility scenario analysis, there is high uncertainty pace of continues change and technological innovation getting adopted global (Nykvist and Nilson, 2015).

The uncertainty and pace of change in mobility is changing along with world population and increase wealth of consumer. This is giving positive indication to personal mobility demand, vehicle ownership, options to increase travel flexibility, safety and convenience. Along with population increase urbanization is on the challenge which need to be address by mobility solutions (MIT 2020). The mobility solutions are focusing on infrastructure creation, compatibility with the density of population and city wise specific activities to define penetration of future mobility (US DOT 2018).

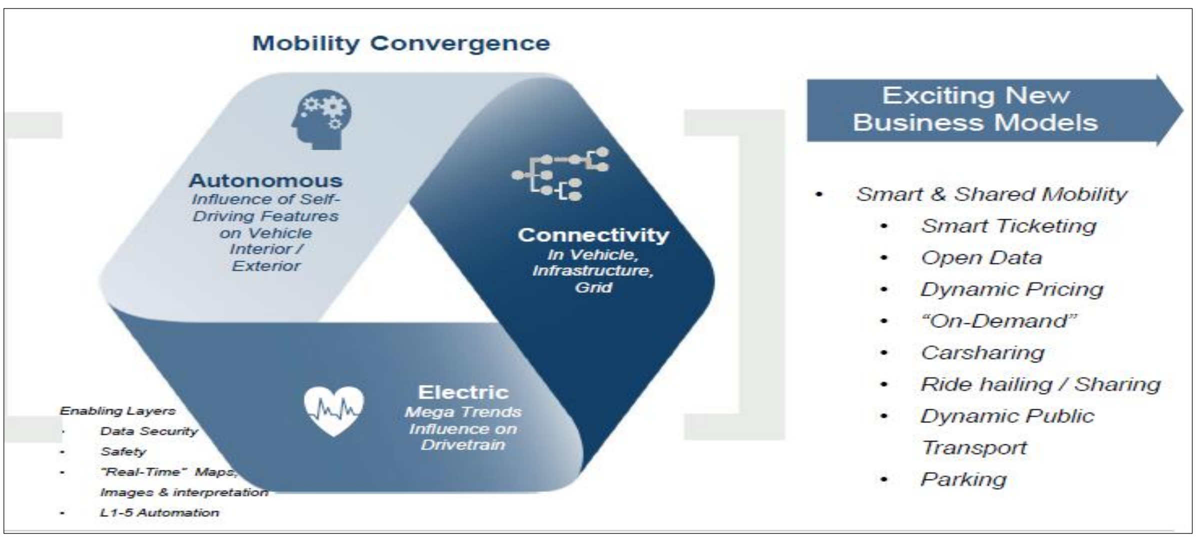
At present majority of counties are showing alignment toward global sustainability policies and responding to environmental challenges. As response mobility alternate powertrains technology, net zero fuel availability, fuel infrastructure and related ecosystem are under development to make sustainable options (Marcel, 2017). The disruptive technologies, business models, conventional lifestyles regarding vehicle ownership, commuting with people and shopping requirements are boosting shared economy, e-commerce and telecommuting.

The forces included in mobility evaluations are complex and in somewhere conflicting. So, to deal with these complex and conflicting forces mobility re-shaping is required. This re-shape a mobility is looks very different from today's mobility. The available research data has noted major forces data that affect the evolution of mobility leading up to 2030 – 2050 and beyond. The current available analysis has explored different factors like consumer preferences and alternate powertrain technologies (Tsamos, 2020). This analysis data is helping to shape the future of mobility in various aspect. The mobility driving forces studied so far in mobility research are navigating further research to address disruptions and transformation that lie ahead (MIT, 2020).

### 2.3 Future Mobility Technology Megatrends

The mobility transformation is driven by mega technologies disruption trends (Toshiba, 2019). The megatrends are alternative powertrain (electrification of vehicles (EVs), hybrid EV (HEV), Fuel cell EV (FCEV), connected vehicle, autonomous vehicles (CAVs), shared mobility and - (mobility as a service Maas)). At present each above megatrend is impacting mobility sector independently (Figure 2.4) and significantly disruption in ecosystem happening with this. As predicted in combination this megatrend can drive unprecedented change which yet to analyze in totality. Each conventional vehicle OEM is concern about this megatrend. The various actions

**Figure 2.4 Future mobility trends (Frost and Sullivan, 2019)**




plans are getting framed around this key transformation trend in different way (Electrical Outlook 2022).

Future mobility trends acronyms are mentioned by different research firm differently.

i. ACES - autonomous, connected, electrical and share

ii. CASE - connected, autonomous, shared and electrical (Foresight 2019)

iii. SAEV - shared, autonomous, electrical (Gocke and Meier, 2022)

iv. MADE - mobility, autonomous driving, digitalization, Electrification etc.

The acronyms are summary of trend to use in various forum. Acronym's arrangement of individual trend is different, but megatrends common in each. The transformation in field of mobility is fueled by significant technologies-driven disruptive trends: electric vehicles (EVs) i.e., alternative powertrains, connected vehicle (CV) and autonomous vehicles (AVs) and share mobility (Maas – mass as a mobility). As mentioned in various mobility research future of mobility is Electrical vehicle to move toward net zero target of sustainability. The technology megatrend other than EV are driven by consumer preference, urbanization, safety, traffic challenge, etc.

### 2.4 The sustainable disruptions

The alternate powertrain (PHV, EV, FCEV), vehicle automation, connected vehicle, shared mobility are megatrends adaption is must for net zero commitment. The net zero commitment is holistic approach focusing on the tempting goals of 6 zero's; zero-emission, Zero-Energy, zero-congestion, zero accident, zero empty and zero cost (Frank, Machielse and Duin, 2020). This net zero goal approach is navigating towards a new economy, sustainable ecology and more time efficient mobility (Rifkin, 2014). Along with other mentioned megatrend net zero is one of indirect efficient terminology to define future mobility efficiently. The megatrend acronyms are used to discuss future mobility conveniently in al various forum

As per mobility driving factors study technology required for future mobility is new and nascent enough. The researchers are just navigating to catch stuffs and few stuff are yet to catch to speed up future mobility market growth. As per revied data, there is lot of uncertainties about rate of adaptions, time span to boost market, technology and business strategies of future mobility. Each mobility megatrend moving as per there space. But future mobility megatrend EV growth trajectory is driven by sustainability commitment (SLoCaT, 2018). So, visibility of EV penetrations is much clear than other megatrends. For this technology-innovation and business strategies have to be defined rightly.

### 2.5 Future technologies emerging in Mobility field along with megatrend

The starts up, OEM advance technology, institutions, universities are doing their research on related technology which can be part of mobility to become Future of mobility. Summary of future technologies mentioned in below fig. indicated related technologies which taking plan in Mobility. The technology refereed for this are entering in mobility sector very fast dependent of ecosystem (Cornet et al, 2012).

The advancement in mobility sectors is set to replace current vehicle-centric system a radically and efficiently. The data enabled system with help to enhance decision making matrix. The further to this data base will help to bring driverless ecosystem very faster than current predication. The transition between public, private, shared mobility, information enabled scheduled modes of transport, etc. is going to be very much important. Each mentioned elements among this going to play role individually as well as in combination (CFM, 2020).

### 2.6 Personal Mobility current and future

From evaluation of vehicle up to today personal vehicle is a centrally high valued feature in human society. The vehicle is essential for the productive functioning of economies and social. In various survey, study and literature mentioned that moving forward there is uncertainty in personal mobility. But few survey, study and literature has shown that personal mobility going to be centrally high valued feature in future mobility as well.  will be one of the centers for future mobility. The kind of technology, trend, factors which going to drive future mobility is unclear.

The benefits of the technologies and systems that is going to evolved to enable mobility on a large scale which difficult to overstate with current available research. However, mobility boom and accessibility of this market growth is concern in long-term as a sustainability of our transportation systems. The mobility space will have a substantial physical footprint which required enormous public and private investment. As per grid analysis, significant current energy resources utilization is a major contributor to greenhouse gas emissions and local air pollution and which boost many other negative externalities (EPA-US, 2020).

Personal mobility land scape and main areas influence

The major 3 policies which are driving 2030 - 2050 sustainability target.

(i) EU level policies to mitigate greenhouse gas emissions excluding commitments associated with Paris Agreement (4°C warner 2012)

(ii) Paris Forever commitments under the Paris Agreement on global climate change to fully implement by 2030

(iii) Paris 2°C commitments to the year 2030 and thereafter greenhouse gas emissions (UN 2015)

By taking refence of these policies, some countries have enforced strict emission regulation. So as integration all this initiate there is big push to look for alternative for mobility. Major car market US and China have very strong ownership pride and fucus on travel. As results of this there is strong requirement of personal mobility. The individual who ascribes more symbolic value to their vehicle have much high likelihood of car ownership.

The research review indicates that the effect of car pride on car ownership is as strong as the effect of income on car ownership. These findings on car pride and generational preferences suggested that consumer ownership perceptions and behaviors are likely to reinforce personal vehicle ownership moving forward (Scarborough, Burns and Jordan, 2012). This may change moving forward by socio-economic revolution or new policy's introduction with active new social norms. So, personal vehicle and heavy/light duty vehicle emission challenge is going to continue and need mitigation to meet sustainability (Hogt, Balm. and Warmerdam, 2017)

### 2.7 Personal mobility and pollution

The various global analysis and data review is available on the CO2 (carbon di oxide) emission. As per data (US EIA, 2018) the vehicles have consumed approximately 400 billion gallons of fuel excluding large public expenditures needed to support road networks and other vehicle-related infrastructure. The personal vehicle and light duty vehicle (LDV) travel approximately generated more than 3 billion metric tons of CO2 (carbon dioxide) emissions every year and contribute almost 40% of total transport sector emissions (Macharis et al., 2014).

The vehicle and other personal transport are going to remain a major source. This is contributing to poor air quality and major public health damages, especially in high dense population urban areas. Due to high cense population and congestions travel time delays roads impose are creating massive economic and social costs. Along with congestion road safety is remains a critical global challenge. As per WEO 2018 data, around 1.35 million deaths are due to vehicle crashes each year (IMF, 2018).

The population and incomes increasing as results of this globally personal mobility is expected to grow in high speed. So as per current analysis urgent attention is required to redefine the policies to address this challenge. In emerging economies at present there is relative low level of levels vehicle ownership compared to develop economy (Andrei et al., 2017). But moving forward emerging market vehicle level ownership is going to increase. As per review 0.5 billion passenger vehicles may get added to fleet by mid-century in the U.S. alone and light duty vehicle expected to increase by roughly 50%. This contributes to around 5 trillion miles per year vehicle travel coverage going to happen. As review number of vehicles and vehicle miles travelled projections are going to increase. This detail is directing attentions toward fuel resource used, climate sustainability factors, pollution impacts, safety and related challenges (Velde and Rieck, 2013).

## 2.8 Personal Mobility status and future

The mobility is central to enables transportation, access opportunities to mobilize, fast track prosperity, improve quality of life and social connections. In global billions of people enjoying personal mobility from few generations onward. The technologies and infrastructure have evolved over last one hundred years to deliver best personal mobility. As per latest mobility trend and requirement current development are not fully satisfying demands in totality in term of safety, road injuries and fatalities. The distribution of mobility in developed and under-develop countries highly unequal, reflecting and perpetuating socio-economic inequalities (UN DoE, 2017).

In metropolitan area day by day traffic congestion increasing and impacting on socio-economies. This contribution is on healthy levels of local air pollution and emissions of greenhouse gasses. The substantial and complicated technology, policies, consumer requirements with respect to cost, convenience, flexibility and preference are central imperatives to develop and deploy more environmentally sustainable mobility options (Ghandi and Pal, 2019).

The continues improvement are happening in personal mobility fuel economy to minimize carbon emissions and continues substantial development happening to deploy electric vehicles. As longer-term plan there is development going on in hydrogen production and fueling. These findings are based on various literature review conducted (Leo, Pachauri and Rajendra, 2014)

As per review further research is needed to explore the role of other forms of mobility beyond personal and light duty vehicles (Andrei et al., 2017).

The careful analysis of multifaceted factors, impact new technologies, consumer preference, policies and market anticipation are required to shape future of mobility to works better for everyone on planet. The multifaceted factors like congestion, air pollution, road safety and greenhouse gas emissions are to be careful considered. Apart from this consideration interactions of factors together with multidimension analysis impacts of different futures, costs and benefits are required.

In totality this might shape a future of mobility which is better for everyone on planet. The substantial emissions reductions Paris to 2°C scenario require actions on many factors like 50% electrification personal mobility and significant decarbonization in transportation sector.

As per literature and current study EVs will contributes majorly to personal mobility and light-duty vehicle by mid of century irrespective of climate policy. Furthermore, climate policies will change the speed of EV penetration and ultimate number on the road over coming years. The decarbonization of EV can be effective boosting progress of electric grid development. As per review is clear that EV policies must go together with low-carbon electricity generation policies.

The hydrogen Fuel cell EVs is another pathway for better decarbonization (Hydrogen council, 2017). But potential of introduction of this technology by mid-century timeline is totally dependent on cost affordability in terms of both vehicles and fueling infrastructure. As per review introduction of personal EV along with more efficient ICEVs can play vital role to reduce global carbon emissions at a manageable cost. Future research and development advancement is required to meet ambitious decarbonization targets. The climate change mitigation required actions from all sectors, economy and personal transportation contribution. This mitigation actions have to be part of an integrated policy to maximize human quality of life, manage climate change risks and secure a sustainable foundation for economy growth and future development (Meyer, Pachauri and Rajendra, 2014).

### 2.9 Future Mobility - BEV, HEV and FCEV toward net Zero

As per review there is high level of fucus on BEV to reduce greenhouse gas emissions. BEV command over FCEV to reduce greenhouse gas emission is going to define by sensitivity of carbon intensity of electricity and hydrogen generation source used to power the vehicles. In various literature BEV lifecycle emission has been studied over FCEV based on the carbon intensity source electricity and today's hydrogen production source.

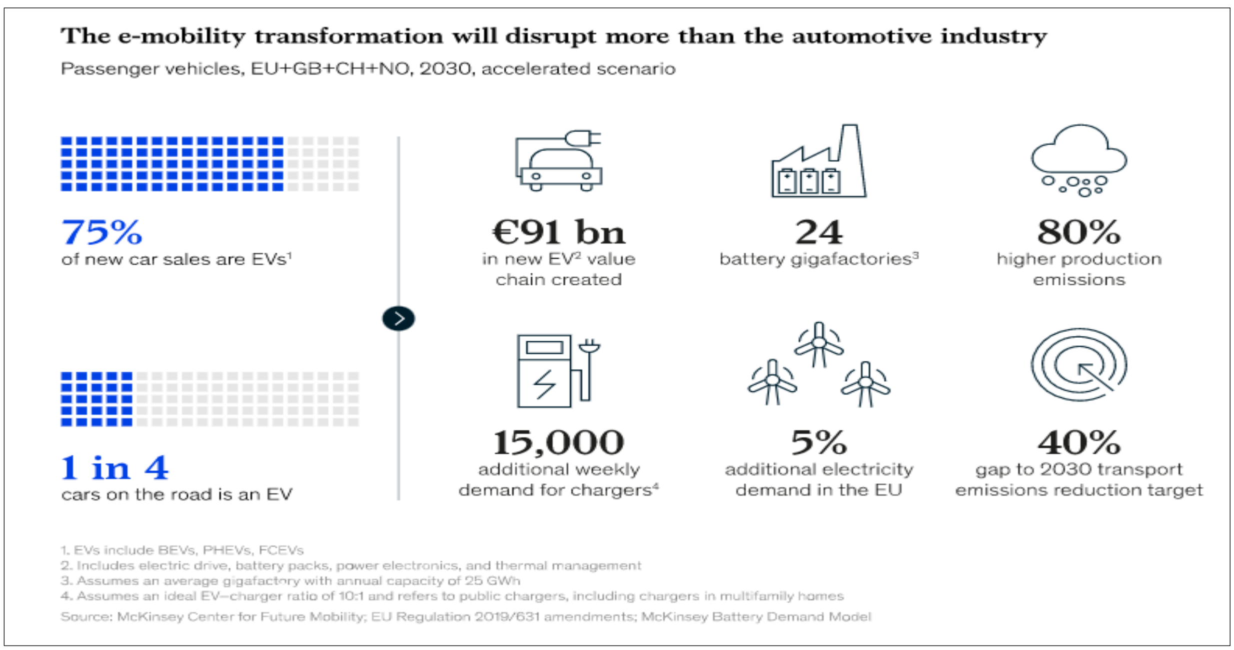
As per objective level data BEVs are most carbon-intensive in the U.S. can emit 30% more CO2 than a comparable HEV provided electricity generation from high carbon intensive power mix (Mackenzie and Heywood, 2015). The same level of BEV can run on electricity generated from least carbon intensive power mix can be 61% better than a comparable HEV. A FCEV runs on hydrogen produced by steam methane reforming process has approximately same level of lifecycle emissions as a comparable HEV. These emissions produced by FCEV can be reduce about 44% using hydrogen produced from alternative process. This level can be reduced to 61% if hydrogen is produced by electrolysis of solely from renewable source wind power i.e., electricity produced from low low-carbon intensive source (Hughes, 2013).

So, adoption of advanced powertrains for vehicle must be review in line with climate change mitigation plan. It should review fuel supply source mix considered to produce electricity and hydrogen. So simply deployment of alternative powertrains is not based on the electricity and hydrogen supply as exists. But it should be dependent on mixed of decarbonization sources which beyond transportation sector.

### 2.9.1 EV as Future of Mobility and current development

Keeping in mind megatrends and preparedness for future OEMS are putting plan for EVs. The extensive macro plan, road map, visions for EV has been displayed by existing OEM and start up with technologies. The existing OEMS has put EV plan w.r.t. current ICEs portfolios. In majority of this plan are in line with respective country government policies alignment and few are proactive to maintain global EV competition figure 2.5. Since BEV is new to world different technology-innovations are getting evolved in current ecosystem of ICEs. Majority of literature and data has mentioned that battery electrical vehicle (BEV) will be future of mobility to overcome global sustainability challenge, meet future regulation and address consumer change behaviors trend (KPMG, 2019). The various are simulated out of this one scenario illustrate that 75 % all category car sales will be EV by 2030. Even with this number of new vehicle sales there will be 40% gap in stated EU emission target.

**Figure 2.5 EV as Future mobility scenario (McKinsey 2021)**



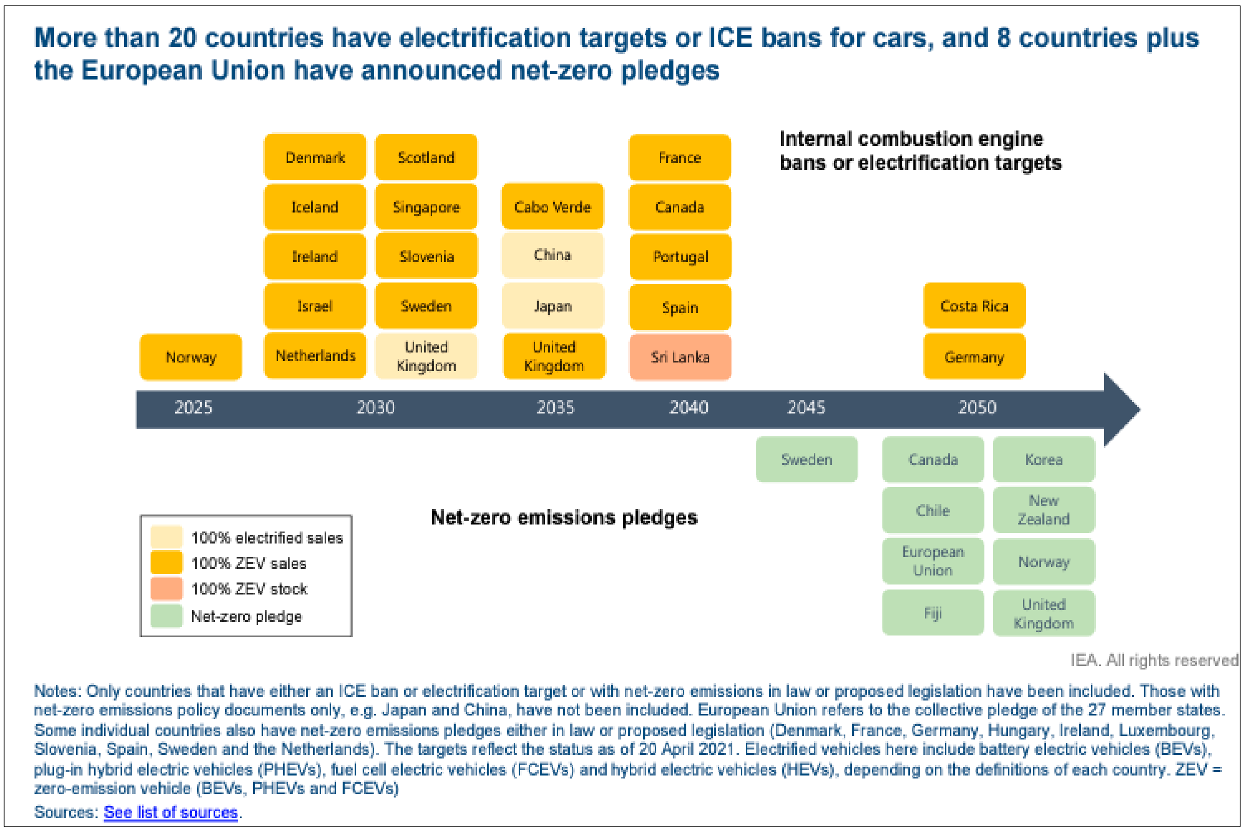

Due to global emission challenge many sectors beyond automotive and transport are being disrupted. This situation is creating challenges as well as the opportunities to new entrants, new emerging markets, existing ones converge and those out of race possibly vanishing. The new entrants and start-ups are challenging incumbents. The current incumbents who turn to leverage their experience and resources are on path to build sustainable market positions. The major literatures are discussing regarding population growth and critical support of mobility to address this change in terms of urbanization, environmental concerns and economic activities. The frequent reviews have brought points to notice like congestion, inconvenience, inefficiency, accidents, safety and high prices. So clear expectation coming forward that future mobility must be convenient, safe and economic mobility, with less impact to health and the environment (Threlfall, 2019).

### 2.9.2 Transformation of EV and OEM

The sustainability is global priority and mobility sector is moving to make sustainable future mobility. The various technology trends are there in mobility sector among that electrical vehicle is one the leading trend transformational trend. The vehicle existing ICEs technology vehicle manufactures are under tremendous pressure to increase current vehicle fuel economy to meet emission level targets and this adding business challenges. By taking all this emission scenario in consideration EV manufacturing doing transformational change to their vehicle manufacturing commitment. These commitments are different in country wise and state wise. Some OEMs has announced the ambitious commitment to make 100 % EV and discontinue ICEs vehicle. Few OEM has done balance declaration keeping EV % and ICE% in consideration to meet emission level target. Alike OEM commitment respective countries has announced their road map for sustainable mobility considering their commitment to Paris or EU agreement. The fundamental for this announcement is to make sustainable ecosystem and mitigate emission challenge which going to emerge.

In global the countries are pushing strong policies for net zero emission. Some country voluntary taking zero pledge. This directly putting pressure on OEM. Figure 2.6 show that Norway is already moving toward 100% EV sale as new vehicle by 2025. Along this there is planning to ban ICEs in some countries. Alike 100 % EV sale introduction there is ambitious plan drawn to go toward net zero emission pledge. UK have plan for 100 % electrified mobility by 2030 followed by China and Japan by 2035. EU countries have zero emission electrical vehicle sales by 2025 and 2030 (IEA, 2020).

**Figure 2.6 EV outlook with net-zero emission pledges (Dulac, 2021)**



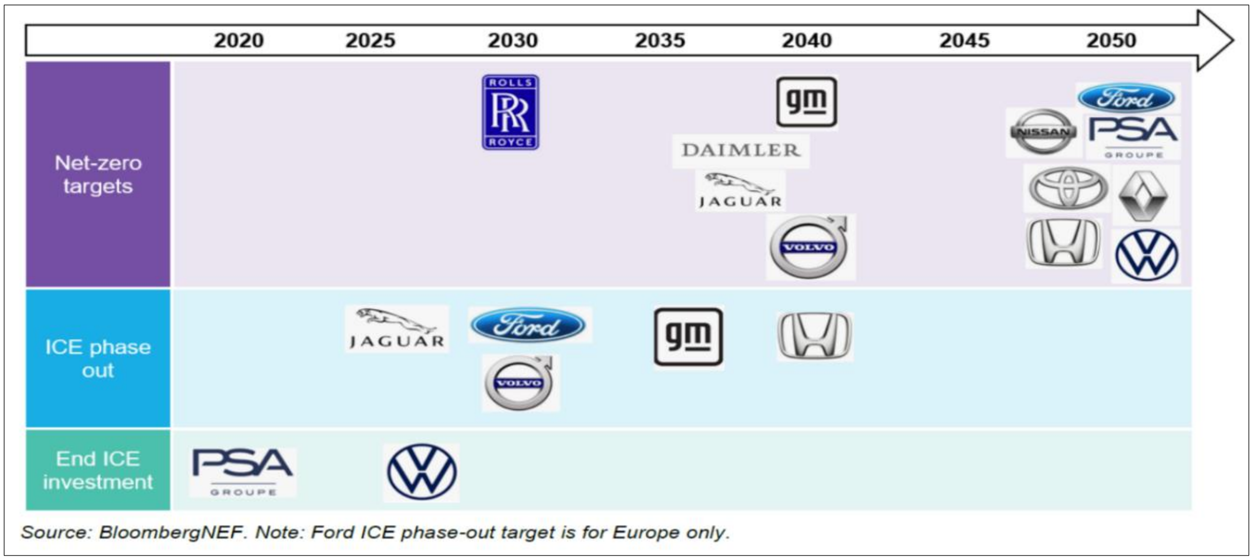

As reflection of country decision, the specific OEM has declared their own road map (Fig.7) to achieve net- zero target of ICE phase out (Figure 2.7) or end ICE investment. This is giving direction to do Technological innovation on alternative powertrain. The electrical vehicle development is majorly driven by regulation and sustainability. Along with this other driver are also there which driving EV development. This EV focus is due to global imitative of sustainability or net zero emission (Yuan et al., 2017). The other future mobility technologies are evolving due to a concern like safety, number of expectations, catch speed of big technology trends (e.g., 4G to

5G, AI, Big data) and expectation of customer. This other are treated individually as well in combination of EV and others. But this are not in focus due like EV pace.

2.9.3 EV and alternative Powertrain

As per review alternative powertrains like HEV, PHEV, BEV and FCEV have strength to impact current ICEs vehicle market and create future mobility market. At start of new technology of BEV there is cost gap between battery electric vehicles and internal combustion engine vehicles.

**Figure 2.7 OEM wise net zero targets (CleanTechnica, 2021)**




This is due to dependence on technology and range of battery electric vehicle. As per current price trend battery costs has decline in past 5 year of span and predicted to decline further on account of raw material cost reduction (US Energy, 2016).

The Battey cost reduction is not only the alone market forces will not support substantial uptake of battery electric vehicles through the cost differences of ICEs incumbent vehicle will persist. This cost analysis is based on in-depth analysis of cost structure of the battery supply chain, raw materials extraction and conversion of battery cell to pack. As per new technology introduction cost difference between electric and conventional vehicles is expected to persist for decade but endeavor to lower operating costs help to offset price BEV (Knittel, 2011).

In most markets traction of this vehicles has lower operating costs w.r.t. conventional ICE gasoline vehicle. The operating cost is influence by price of electricity (at home and charging stations), gasoline prices in same market, vehicle maintenance costs, total battery economy and ambient temperature which decide electric-vehicle efficiency. Along operating cost total cost of ownership is likely going to shape adaption of new vehicle technology

The factors besides total cost of ownership will likely shape the adoption of new vehicle technologies, consumer familiarity on availability, easiness of charging and fueling infrastructure. If new vehicle technologies like electric vehicles are adopted on a large scale, this will create opportunities for new business and required cost-effective methods for end of line technology for batteries on an industrial scale (Inglis and Dutzik, 2014).

In this scenario life cycle emission of vehicles is going to be highly sensitive in process it used to produce and distribute the fuels (electricity or hydrogen) on which they operate. This indicate that the battery electric vehicle which going to operate on green electricity mix will have much lower greenhouse gas emissions than current ICEs, HEV, BEV operate on carbon-intensive electricity. At present BEV are operating (in most of China and in some parts of U.S.) majorly on current conversion of electricity grid mix will create higher emissions than hybrid EV. As per current literature charging speed and proximity of charging stations to common destinations have more influence on electric vehicle adoption than the total number of public charging stations (US Energy, 2016).

### 2.9.4 Future mobility BEV and ICE

The greenhouse gas emissions per mile or per kilometer for BEVs are approximately 55% of ICEVs for equivalent size vehicle. The emission projected for BEV in comparison of ICEs are mainly due to greenhouse gas emissions come mainly from the ecosystem used in production of electricity and hydrogen. In contrast to this, most ICEV and HEV emissions is come from the combustion of fuel on board the vehicle which is visible directly on tail (Yang, Chen and Isenstadt 2018).

The emissions associated in battery manufacturing vary substantially across type of powertrains, but these differences are generally dwarfed by greenhouse gas emissions from the fuel lifecycle. So due to this relative emission of battery electric vehicle production and used electricity generation by conventional source is becomes more substantial than ICE engine as the fuel's combustion. So, emission of BEV is much more sensitive to the carbon intensity of the used power grid. As result of this geographical emissions variation is much greater (Hong and Wang, 2012).

The demonstrative study has been conducted on BEV manufactured and change on electricity produced in USA and China. As per this study US BEV produced 25% less emissions than HEV, whereas China average 13% higher greenhouse gas emissions than a comparable HEV. These results show major differences in the carbon intensity of electricity power grid mix between these two countries.

As per overall sustainability projected target over the next three decades i.e. up to 2050 emission has to be reduced by 30%–47% for BEVs, by 20%–40% for ICEVs and by 25%–40% for HEVs.  But in carbon intensity of U.S. grid declines by this period by 50%, then benefits due to BEVs over for ICEVs and HEVs will not be significant.

In other hand if cardon intensity of the grid declines dramatically up to 92% by this period, BEV emissions would decline from roughly 75% to 37% compared to HEV. But emission due to FCEV is dependent on source of hydrogen produced. It is possible to reduce 61% lower emission by FCEV compared to same size HEV by using renewable sourced based hydrogen (Davis et al., 2014). The by using coal sourced based hydrogen FCEVs greenhouse gas emission will be 56% higher compared to HEV and 14% than ICEV. There is possibility to reduce the emission happen due hydrogen production by capturing and storing produced. The FCEV run on stream methane hydrogen is producing emission roughly equal to HEV and further reduction approximately half possible by adding carbon capture to steam methane reforming.

### 2.9.5 Future of mobility with Battery technology

The battery technology is one driving factor for future BEV. At present the cost of battery is one of challenge to make BEV competitive and sustainable w.r.t. ICEV. The conventional one-stage learning curves shows cost of battery will declining as a function of production volume and battery production cost. The models so far used to predict cost reduction of battery are based on one-stage learning curves. As projections battery prices will fall below $100/kWh by 2030 which can bring BEVs closer to ICEVs irrespective of the incentives (Schmidt et al., 2017).

However, these projections are too optimistic by using conventional learning curve model for cost reductions identification. It is unrealistic to expect that price of battery continuously fall as cumulative production volume and efficiency increase irrespective of prices of materials made price reduction. As per literature reassessment is required on model or productions which used to reduce battery cost.

The battery cost reduction by increasing production and manufacturing efficiency have limited potential. But base input material base cost reduction has better opportunity for cost reduction. In current literature two-stage learning curve model has been studied to reduce cost and as per analysis this model has potential to achieved targeted cost for wide adoption of EV by 2030 (Berckmans et al., 2017).

As per current development detail and literature lithium-ion battery chemistry and technology is dominating the electrification of the mobility. This chemistry and technology are dependent on expensive metals. The technology and innovations in this battery chemistry are needed to reduce the floor price of batteries and boost electrification of the mobility (Knupfer et al., 2017).

Along with lithium-ion battery for greater cost reductions other battery chemistries and technology (like lithium or lithium sulfur, sodium ion, solid state and multivalent-based) must be explore as mainstream choice for mobility electrification manufacturers beyond 2030 (Knittner, Felix and Kammen, 2019). The battery technology has explored for electrification of mobility to make mobility emission free. But the environmental emission concerns regarding battery disposal and recycling are growing along with supply chain growth.

So as per literature technical and emerging business solutions are expected for battery recycling to make future (knupfer et al., 2017). The current EV batteries major cost portion is drive by base mineral material. For sustainable and cost-effective battery technology different battery chemistry, recycling at end of the useful life, technology-innovation and business strategies are needed to explore moving forward (Knittner, Felix and Kammen, 2019).

### 2.10 EV charging and alternate fuel Infrastructure

The adoption of electrical vehicle is dependent on strong charging infrastructure. Similarly, fuel cell vehicle adoption is depending on hydrogen fueling infrastructure pattern. The charging speed and availability of charging stations at common destinations have impact on electric vehicle speed adoption. As per data publish in 2019, charging electric battery vehicle at low power in home is primary way follow by owner. In long rum once electric vehicle penetration increase there will be constraint of charging space and power capacity to household (OICA, 2019). The workplace charging is partial solution for home charging. But option have limitation of capacity, space and costs. The important solution is to add the fast public charging station (Chlebis, et al., 2014).

The hydrogen is important source to do decarbonizing created by mobility. The introduction of hydrogen is interlinked with other sectors. As per analysis hydrogen can support as a major contributor to meet net-zero emissions target. The hydrogen can perform potential role in decarbonization in multiple economic sectors by massive production hydrogen, innovative distribution, storage technology and ecosystem to utilize. This will help to develop fuel cell electrical vehicle technology as future mobility. Which can be benefited to light and heavy commercial vehicle. At present hydrogen fueling station infrastructure is major challenges ( Simbeck and Chang, 2022).

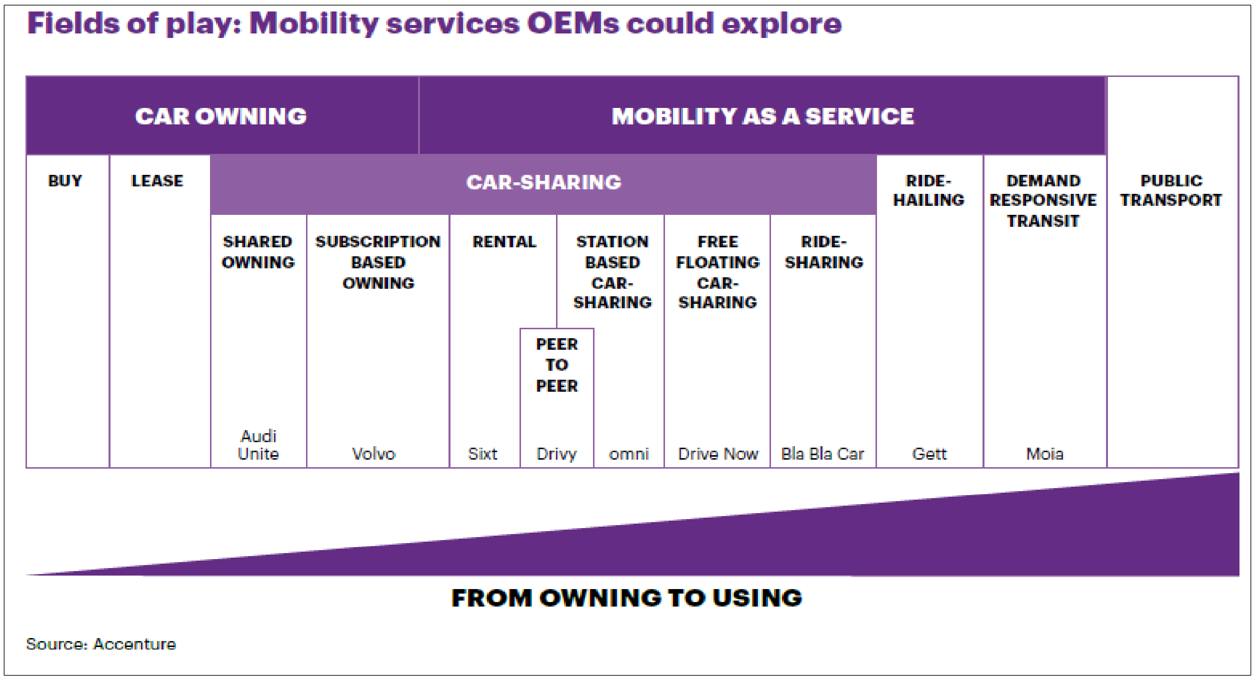
As per present data, 85% BEV owner charging battery at home. Since dependence on public charging have challenges, inconvenience and high operating costs. As per location data vs charging cost analysis, the retail cost of fast charging of BEV at public charging station exceeds cost of fuel of ICEV on a per miles/kilometre basis. As per current infrastructure neither BEVs have enough charging station (home charging or public charging station) nor FCEVs enough hydrogen fuelling station. As per data publish by AFC TCP 2019 worldwide 376 hydrogen fuelling station are available including both public and private stations (Simbeck and Chang, 2022).

At present there is challenged to make cost-effective hydrogen manufacturing, storage, distribution and other concern various elements impacting on FCEV base future mobility. The analysis of the Beijing taxi fleet show that battery swapping is currently not feasible option for personal vehicles. This option could be feasible in large, closed and dense systems where electrification has been mandated. The battery swapping systems is depends on avoiding downtime for charging.

### 2.11 Mobility as a Service as future mobility

Along with sustainable alternate powertrain vehicle (BEV or FCEV) the substantial development is happening toward area of mobility service. The is paradigm shift has been seen in vehicle ownership to vehicle Usage.

**Figure 2.8 Mobility service exploration for OEM (MaaS, 2017)**




The industry moving very quickly from public and private transport being separate businesses to integrated multi modal mobility network. This is happening due to changing demographics, preferences and technology (Lewis, Garling, and Loukopoulos, 2008).

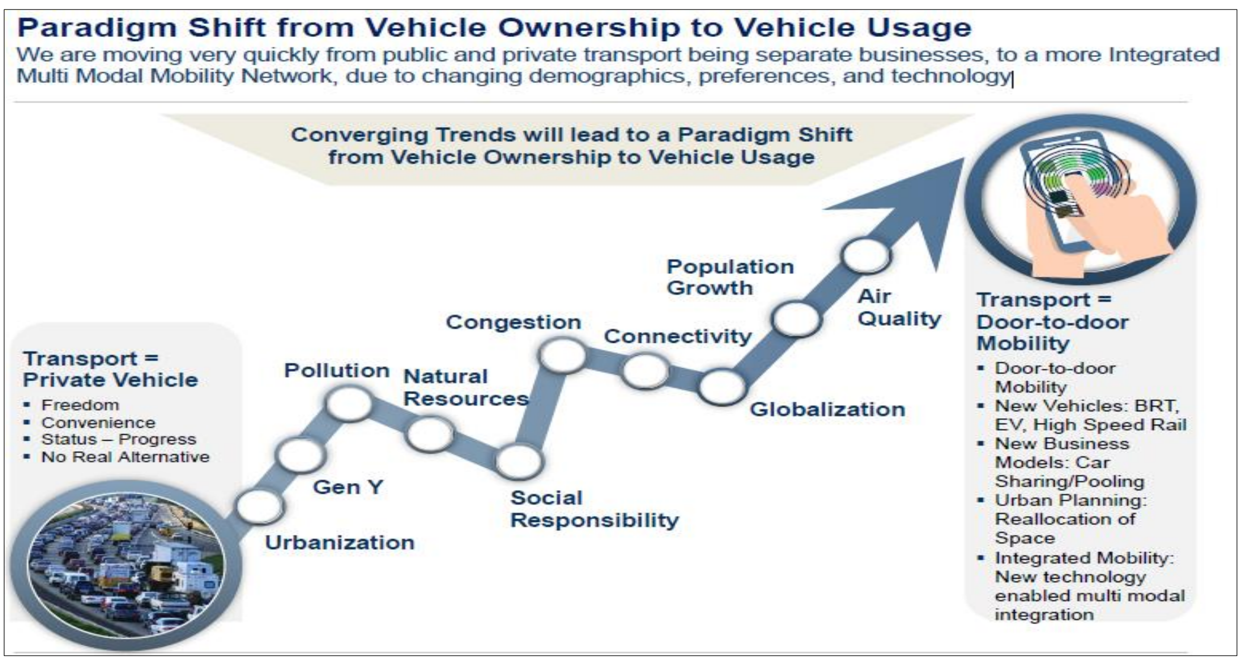
The evolution mobility service evolving is continuously. The vehicle OEMs are setting up plan to move as a strong mobility service player. The car company car companies are transforming by selling car to service proving companies (Fig.8). Which are providing solution to new customer by giving services and mobility solutions to target and create platform for future proof business (Lewis, Garling, and Loukopoulos. 2008).

### 2.11.1 Mass as a Service Technology and business strategies

The new mobility services are providing better solution and creating futuristic business. These solutions have own challenges like exacerbate congestion problems in some urban areas. They are attracting riders away from mass and public transit. The commercial point of view on-demand mobility services is much costlier than private car ownership and reason are differ from reason to reason. In long term point of view the success of on-demand business are dependent on government intervention and subsidies. As per data, development on autonomous vehicle is going on to reduce cost of on demand service. The autonomous vehicle is required significant human oversight (KPMG, 2017).

The mobility service has broad implications at different places and affects everyone (Figure 2.9). It is impossible to address all issues involved in mobility change over process. So, the mobility service changeover has been selective considering focused on policy and technology scenarios. The current human transportation service and options are depending on the policies, on technology options and valuation system adapted (Inglis and Dutzik, 2014)

**Figure 2.9 Future mobility trends (Frost and Sullivan)**



### 2.12 Introduction Autonomous Vehicle

At the level of individual consumers, literature suggest that optimistic perceptions of AV safety may create a market for early adoption among young, male, highly educated, high-income, urban and car-consuming individuals across all countries. The rest of the population remains more sceptical of the potential for AVs to be a safe alternative mode of transportation. At the country level, initial evidence that public perception may drive faster adoption of AVs in developing countries, potentially improving road safety in countries that face the greatest road safety challenges (Arem, Rieck and Boersma, 2018). The variation in AV awareness, perceptions, predictions of future AV safety are attributable to individuals but significant variation at the country level. There are areas of uncertainty for AV like when and how AVs will disrupt current mobility systems. The AV for personal and fleet required different level of planning and additional consideration (Karla and Susan, 2016).

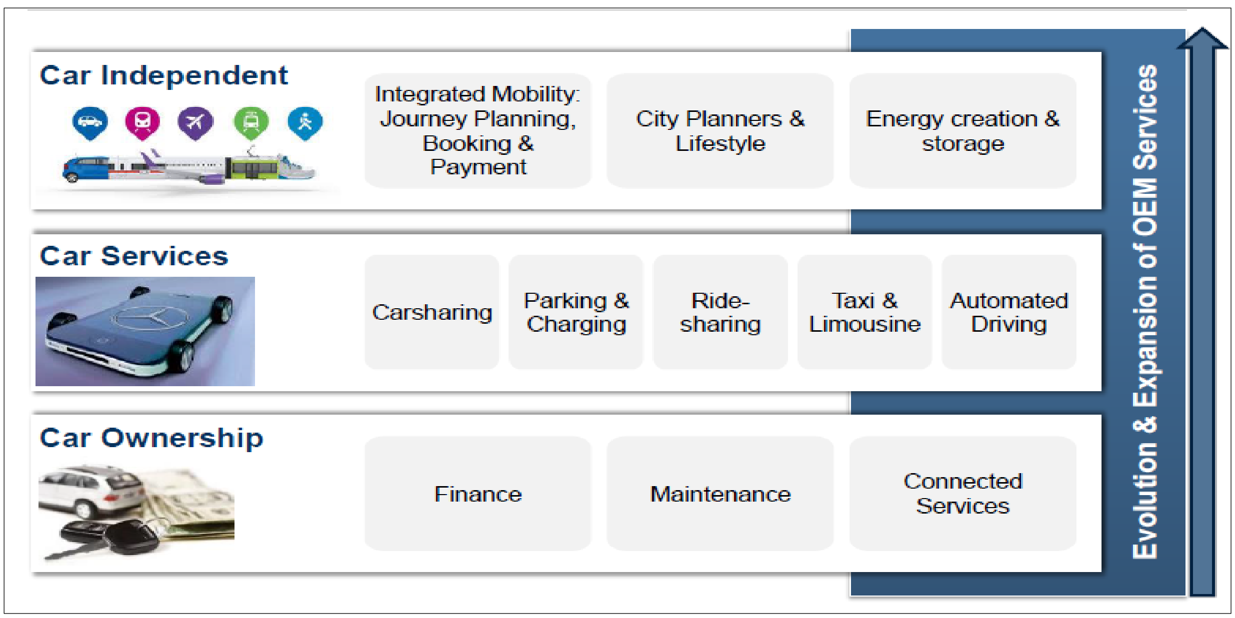
There is uncertainty around AV interaction with current mode of transportation, infrastructure, consume behaviours and regulatory frameworks. The important factors around which AV evolving are safety and traffic congestions. Technology is developing very fast in area of AV. But realisation of this required solution around legal, economic and political barrier. As per predication AV may be safer than human-driven vehicle on the roads (Kockelmanb et al., 2017).

As per current outlook AV technology and fleet of AV like on-demand mobility services are less clear and not close to the maturity. The new mobility services are existing and under continues development but impact of this on congestion and energy use are impacting sustainability negatively. There is development in progress for alternate powertrains and significant efforts are ongoing for autonomous vehicle. Due to this current mobility business model are moving away from the current dominance of private own car to shared mobility services. The urban area is growing continuously every year with much increase concentrated population density. Due to this moving forward mobility going to become one of the challenges in urban area. The challenges are like traffic congestion and growing air quality (FoM DOT, 2019)

### 2.13 Introduction Future mobility Total cost of ownership

The world population and incomes are increasing. Due to this mobility is reaching to hundreds of millions more consumers. Along with few points are remains uncertain like clear mobility evolution roadmap, changes required in mobility to addressing public policy requirements, reducing of city congestion and action plan to meet global climate challenge (Charles et al., 2018). The much intensive further analysis is required on drivers (i.e., technology, economics, policy and consumer behaviors/preference) which potentially impacts and interact with one another (Figure 2.10).

**Figure 2.10 Future mobility trends (Frost and Sullivan, p. 9)**




The current battery electric vehicle trend has economic and technological challenge w.r.t. ICEs vehicle. The challenge is battery cost and range of vehicle even though there are subsidies are available in some countries. In BEV total cost of ownership analysis is sensitive factors including ICE fuel prices, electricity price, maintenance costs fuel economy of ICEs, vehicle life, battery life, battery size, subsidies rate, country wise taxes and insurance. The BEV are more favorable in some countries where electricity price is less compared to ICEs vehicle fuel prices (Bentley et al., 2019).

The challenge face by high milage drive is high charging cost at public charging station compare home charging cost.  Along with total cost of ownership other important multiple factors are there to determine consumer decisions regarding BEV purchases. As per current available infrastructure ICEs vehicle will be remain the least expensive to manufacture for many years to come. The emission and fuel economy regulations are increasing manufacturing costs for ICE vehicles. The ICE vehicle fuel that complies with pollutant (CO, HC, NOx and PM) criteria of regulations are expected to remain less than the upfront cost of comparable BEVs, FCEVs and beyond 2030. As per one dimensional cost analysis current price premium for BEVs and FCEVs over ICEVs will reduce as battery production volumes and efficiency. But as per the available analysis manufacturing costs for BEVs are expected to remain higher than for ICEVs well beyond 2030. But as per of total cost consideration lower per-mile costs for fuel (electricity) and lower maintenance costs can attracted by BEVs w.r.t. ICEs vehicle to reach parity (Kalplus, Kishimoto and Paltsev, 2015).

The TCO is driven by many factors, including subsidies, fuel economy, gasoline price, electricity price and battery costs—all of which are subject to uncertainty. As per present analysis BEVs cannot compete directly with ICEVs for TCO without the support of subsidies and regulations, except in a few countries, such as Norway, where gasoline prices higher than electricity prices. As per analysis battery costs of BEV decline will help to reach TCO parity even without government subsidies in additional countries where gasoline prices are high compared to electricity. But this estimate is sensitive to various uncertainties which are varying from country to country and region to region. The BEV price reduction and a financially reasonable discount rate can bring TCO but consumer behavior toward ICEVs will continue to be viewed as the more affordable by 2030 and beyond. The review has illustrated that only financial parity will not bring faster and wide adoption of sustainable alternate powertrain vehicle.

### 2.14 Decarbonization advance Future mobility Technologies

The road transportation is broadly split into passenger travel and goods transport (freight). The vehicle type split is classified as below.

i. light-duty vehicles (called as “cars”)

ii. sports utility vehicle

iii. light duty truck

iv. “Heavy” or heavy-duty vehicles include “trucks”, split into heavy and medium trucks

v. buses and

vi. various vocational vehicles.

The of greenhouse gas emission generated from road transport, is a divided as passenger vehicle and good transport vehicle. The global greenhouse gas emission is rising due to all modes of road transports. Among this heavy-duty vehicle used for good transportation (freight) have major contributions (IEA, 2020). In most developed contrived investment in happening toward low carbon fuels and technologies and remains locked-in to the dominance of privately-owned, fossil fuel powered vehicles (IEA, 2019). The emission from total transport sector is about 24% (CO2 emissions from vehicle fuel combustion), along this three-quarters approximately from road vehicles (IEA, 2020).

The emission from transport sector is increasing at same time, vehicle ownership rates are quickly increasing in many developing countries such as China, India and Russia. The global GHG emission will be keep increasing with current available technology. The global transport emission is expected to grow further. So, greenhouse gas (GHG) reduction is required additional of strong climate policy mixes (Axsen and Woloinetz, 2020). At present transport sector has energy mix include 90 % of fossil fuel in 2020.

As per the international energy agency’s (IEA) net zero emissions (NZE) scenario, this energy mix need to change to 45% electricity, 28% hydrogen-based fuels and 16% bioenergy fuels in 2050 (IEA, 2021). But same time, transportation sector demand forecast is to grow rapidly in the

NZE. As per this data from 2020-2050, globally passenger travel demand is expected to double and light-duty fleet expected to grow from 1.2 to 2 billion vehicles. The goods-movement or freight is expected to increase by 250% from 2020 to 2050.

This is one of the reasons, many nations pursuing goals to increase substantially zero-emissions vehicle (ZEV) sales and deep decarbonization. As per most recent COP26 (26th UN Climate Change Conference) 39 nations, 51 cities, states and regional governments agreed to put efforts towards ZEV 100% sales by 2035 and no later than 2040 (GOV.UK, 2021). As of late 2021, Norway country has committed to 100% ZEVs of new cars by 2025 (Norway), eight countries have committed to the goal by 2030 (Denmark, Iceland, Ireland, Israel, Slovenia, Netherlands, Singapore and UK) and five countries by 2035 (Cabo Verde, China, Japan, the UK, Canada and the EU) (IEA, 2021).

The United Nation (UN) and Global Environment Facility (GEF) have launched the Global Electric Mobility Program (GEMP) to assist 27 developing countries to shift to (zero emission vehicles). There is a need to enhanced development of low carbon transportation technology along with this strong need for climate and innovation policies to support. COP-26 Decision 1/CP.26 emphasizes the need for enhanced financing and technology transfer for low-carbon technology.

The various decorbanisation technology development, readiness, diffusion has been studied in various perspective. It includes plug-in electric vehicles (PEVs), advanced liquid biofuels, hydrogen-powered fuel cell vehicles (FCEVs), shared mobility modes and vehicle automation.

The specific objectives of decorbanisation technology study for future mobility is as below.

1. Provide an overview of the technologies and their state of play, including information on their technology readiness and potential climate change mitigation impacts.
2. Briefly summarize some social, institutional, economic and business opportunities related to their development and effective deployment; and
3. Identify innovative policy options, opportunities and challenges for policymakers to effectively support the deployment of these technologies.

### 2.14.1 Perspectives on carbon impacts for road vehicles

i. The tailpipe emissions reports, only what is emitted by the vehicle during operation. In this perspective, PEVs and FCEVs are zero-emissions. This calculation method ignores other carbon impacts which is there at production, extraction or refining of fossil fuels, generation of electricity or production of biofuels or hydrogen.

ii. Well-to-wheel (WTW) emissions considers the full impacts of the fuel, including production biofuels and hydrogen and the generation of electricity. The well to wheel (WTW) emission is measured in grams of CO2 equivalent per megajoule (gCO2e/MJ).

iii. Full lifecycle analysis (LCA) considers WTW emissions associated with the fuel and the vehicle. The vehicle emission impacts typically include the production, operation and disposal of the vehicle and all its components.

The technologies and fuel feedstocks wise emission impact has been studied in past. This impact study has concluded that there is high uncertainty and wide ranges of emission especially by region to region. The data base of WTW and LCA are more well-known for both research and policy, greenhouse gases, regulated emissions and energy. This is studied in GREET (greenhouse gases, regulated emission and energy used in technology) model at Argonne National Labs. The advance decarbonisation technologies for the road transportation are under development and diffusion stage. The below technologies are expected to play important role in NZE (net zero emission) initiative.

1. Plug in electric vehicles (PEVs)
2. hydrogen-powered fuel-cell electric vehicles (FCEVs),
3. advanced liquid biofuels
4. shared mobility modes
5. full vehicle automation.

The readiness of above technologies has been studied. The highest readiness of the technology observed is for light-duty passenger electrical vehicle (PEV) and passenger bus. This both hold strong potential greenhouse gas (GHG) emission reduction and subsequent substantially. The readiness of Fuel cell electrical vehicle (FCEVs) is lower at present. The FCEVs technology is expensive for light-duty and heavy-duty applications at present. The limited hydrogen refuelling infrastructure and concern to assure the hydrogen produce to be green hydrogen. Even readiness of the advance fuel cell is also low. There are potential advantages of the blend fuel with existing gasoline and diesel engine. But in last decade is limited penetration and development of the of low-carbon biodiesel and ethanol.

The reduce personal mobility and shifting away from private vehicle ownership is one of the initiatives to move toward sustainable mobility. In this area the several forms mobility has been evolved like car-sharing, ride-hailing and micro-mobility. But none of this mode of mobility has displaced privately owned vehicle. Even the demonstration of the sustainable mobility is not clearly evidence with a net carbon benefit. The vehicle automation technology is at nascent stage. But the future impact of this technology is extremally uncertain. So, this technology must be aligned with low-carbon fuels technology, the greenhouse gas reduction technology, mobility as s service and vehicle automation to achieve sustainability.

There are several initiatives of climate policy. The initiative such as,

1. carbon and road pricing
2. Market-oriented regulations
3. Financial and non-financial subsidies
4. infrastructure provision
5. research and development support

As per available studies and research, the policy mixes will be successful if this guided by combination of strong regulations and pricing. The deep decarbonisation goals for the road transportation required strong policy mix and identified technologies support. The technological innovation has role to promote economic growth while achieving climate and sustainability goals. The potential focus technological innovations have been identified for transport sector. As per various report transport sector is responsible for 24% CO2 direct emissions (major from fuel combustion) and about 75 % from road vehicles (IEA, 2020). Even though in past decade the investment has done for low-carbon fuels technologies. In the developed countries still there is dominance of privately-owned fossil fuel powered powertrain vehicles (IEA, 2019). The vehicle ownership rates are quickly increasing in countries like India, China and Russia. So, in these countries with current level of climate policy mixes emissions are expected to grow (Axsen, Plotz and Wolinetz, 2020). The strong policy mix in this market is required. By taking this refence, many nations and regions are pursuing goals toward zero-emissions vehicle (ZEV).

As per the 26th UN Climate Change Conference (COP26), 39 nations and 51 cities, states and regional governments agreed to work towards 100% ZEV sales by 2035 and no later than 2040 (GOV.UK, 2021). In 2021 Norway has committed to 100% ZEVs of new cars by 2025. The eight countries (Denmark, Iceland, Ireland, Israel, the Netherlands, Singapore, Slovenia and the UK) have committed to the goal by 2030. The five countries (Cabo Verde, China, Japan, the UK, Canada and the EU) by 2035 (IEA, 2021a). In 2019, the UN and GEF (Global Environment Facility) have launched the GEMP (Global Electric Mobility Program) to assist 27 developing countries in shifting to ZEVs. This is defined after assessing need of the low-carbon transportation technology and to support corresponding climate policies. The COP-26 decision, highlighted need to enhanced financing and technology transfer to achieve low-carbon technology. The objective of this COP report is to identify, analyse development, diffusion and impacts. The advanced decarbonization technologies focused are electrical vehicle, advanced liquid biofuels, plug-in electric vehicles (PEVs), hydrogen-powered fuel-cell electric vehicles (FCEVs), mobility as a service and autonomous vehicle. The report has categories the range of mitigation solutions and policies. This report has considered categories used by policymakers in United State of America and elsewhere in North America (Eggert and Sperling, 2014). The mitigation solutions in the transport sector are classified into 3 categories.

1. Reducing grams of CO2 equivalent per megajoule or gCO2e/MJ by switching to low-carbon fuels. This is focused on technological innovation as below.
   i. this is by switching from conventional fossil fuels to electric vehicle
   ii. hydrogen and advanced liquid biofuels
2. reducing megajoules per km or MJ/km, improving vehicle efficiency.
   The electric and hydrogen fuel-cell vehicles also offer improvements in efficiency (MJ/km)
3. fewer vehicle travelled or VKM, reducing vehicle travel, either from mode switching or reduced travel. The International Energy Association (IEA) has flagged as important scenario and facilitate policies comparison.

The regulations and policies are target specific pathways for fuel-switching or efficiency improvement (example - low carbon fuels standards and ZEVs or improved vehicle efficiency). The PEVs or FCEVs are focused on the purchase incentives for or two low-carbon technologies. The policies' introduction for improved shared mobility have target is to reduce VKM. But this also have societal goals like equity improvement and reduced traffic congestion.

### 2.14.2 Methodological approach for Net Zero emission vehicle

The net zero emission (NZE) help to navigate the potential way for each deep-decarbonization technology in transport sector. This is helping to integrate input from a wide range of transportation experts and stakeholders. The vehicle lifecycle assessment has workout by International Council for Clean Transportation (ICCT) to analysis GHG emissions of vehicle in the Europe, US, China and India (Figenbaum, 2017). This is included energy powered soured by grid electricity or hydrogen. The battery-electric vehicles (BEVs) are powered only by electric motors and plug-in hybrid electric vehicles (PHEVs) can be plugged in or powered by an internal-combustion engine. The PEVs is split between light-duty vehicles and heavy-duty vehicles.

### 2.14.3 Light-duty plug-in electric vehicle

**Technology background**

The BEV components specification varies across different makes and models. The novel components of a BEV are the large, advanced battery and electric motor, while a PHEV also includes an ICE. The PEVs sold in 2020, the global average battery capacity was 55 kilowatt-hours (kWh) for BEVs and 14 kWh for PHEVs (IEA, 2021) with considerable variation across makes and models. The electrical vehicle range from 2020 in North America and Europe is as low as 175km to over 500km (Tesla Model 3). The range of PHEV is varying from 25km to 75km electric in addition to 500 to 800km range of ICEs driving range. The globally light duty BEV and PHEV was having range 350km and 50km by 2020 (IEA, 2021). In 2020 there were 40% increase in PEV sale compared to 20202 and 370 different PEV car models available for sale (IEA, 2021).

The vehicle manufacturers have announced the passenger electrical vehicle, some traditional ICEs vehicle manufactured declared plans to cease their production ICE vehicles in the coming decades (GM's plan for 2035 and Honda's goal for 2040). In electrical vehicle advance development is going on battery performance improvement. The battery performance has included 7increase in power and energy density for longer range vehicles with quicker acceleration. The prices of lithium-ion battery packs have seen reductions (in 2010 - $1200/kWh to 2020 - $140/kWh in 2020 and in 2021 - $132/kWh) (BloombergNEF, 2021). However, further technology development and cost reductions will be needed to help meet 100% ZEV sales goals.

The PEVs charging can be categorized by location and speed. As per current charging infrastructure, charging location is home with slow charging (power below 22 kilowatts (kW)). The public charging infrastructure have slowed and "fast" charging (22 kW or above respectively). The faster charging includes direct current (DC) fast chargers that operate at 50 kW to 250 kW and can recharge a BEV battery by 80% in about 15 to 45 minutes. The number of publicly accessible chargers increased from 2019 to 2020 by 45%, reaching 1.3 million units. 30% of these were fast chargers (IEA, 2021). In 20202 China was having highest numbers of public chargers, followed by Europe, US (IEA, 2021).

The rest of countries in the world have small number of slow and fast chargers even though relatively high ratios of public charging infrastructure to PEV stock in Japan, Korea, Indonesia, Chile and South Africa and (IEA, 2021). In 2022 public chargers are 1.3 million and as per NZEv scenario assumption it will be 40 million in 2030 and 200 million in 2050. The development is going on in the area of the charging infrastructure like "smart charging" technology. This is helping PEV charging infrastructure integration with grid (IRENA, 2019). The smart charging infrastructure will help to reduce electricity costs and GHG emissions by integrating intermittent and renewable electricity (Axsen et al., 2018). These smart charging technologies are beyond the scope of this report but could be explored further in next steps.

**Light-duty plug-in electric vehicle - Market penetration**

By 2020 10 million light duty electric vehicle (PEVs) was on the road and 3 % vehicle added in stock. (ICCT, 2021a; IEA, 2021a). These PEV sales rates varies from country to country. The few country details as below,

1. Norway (75% of new market share being PEVs)
2. Sweden (35%),
3. Netherlands (28%),
4. Germany (14%),
5. UK (11%),
6. France (11%) (IEA, 2021c).

In the Europe new vehicle market share is 10% in 2020, in China (6%) and in the US (2%). The small fraction of the PEV sales and stock other than these 3 markets. In Japan and New Zealand PEV sales has declined about 10 %. The countries like India and Chile have negligible PEV sales (IEA, 2021). The 2wheeler and 3 wheelers sales in the India and in African countries is dominant (such as Uganda and Kenya).

**Light-duty plug-in electric vehicle – carbon impact**

The greenhouse gas emission of the PEVs depends on a wide range of factors as below.

1. vehicle type
2. drive cycle
3. electricity grid mix
4. timing of charging
5. battery production and
6. New vehicle that is being replaced with old

Even though these factors details impacting, clear that PEVs can play important role in the GHG emissions reductions. The results of studies conducted by using LCA and WTW method are indicated PEVs can reduce emissions by 60% to 95% in comparison with to current conventional ICE technology vehicles (Ambrose et al., 2020; Hoekstra, 2019; Axsen, Crawford and Kamiya, 2019). The recent studies conducted for PEV with full LCA of the GHG emissions from in 2020 and in 2030. The emission impact comparison studies are done for US, Europe, China and India (ICCT, 2021). This study has considered the full GHG impacts of PEV production, manufacturing of vehicles and batteries, consumption of fuels and electricity and lifetime maintenance. As per this study by 2030 GHG reductions tends to be more significant due to use of lower-carbon electricity grids, along with other expected required changes. As a summary over PEV lifetime, the medium-sized size battery electric vehicle can reduce GHG emissions as below relative to a comparison with ICE in each region as follows:

- Europe: in 2020 - 66-69% and in 2030 - 74-77%
- United States: in 2020 - 60-68% and in 2030 - 62-76%
- China: in 2020 - 37-45% and in 2030 - 48-64%
- India: in 2020 - 19-34% and in 2030 30-56%

The PHEV greenhouse gas impact is uncertain compared to the BEV. Since there is unknown % of the driving powered by grid electricity versus gasoline in the ICE. As per 2020 study the medium-sized PHEVs GHG benefits is as below with relative comparison with an ICE (ICCT, 2021):

• Europe: 25-27% reductions

• United States: 42-46% reductions

• China: 6-12% reductions.

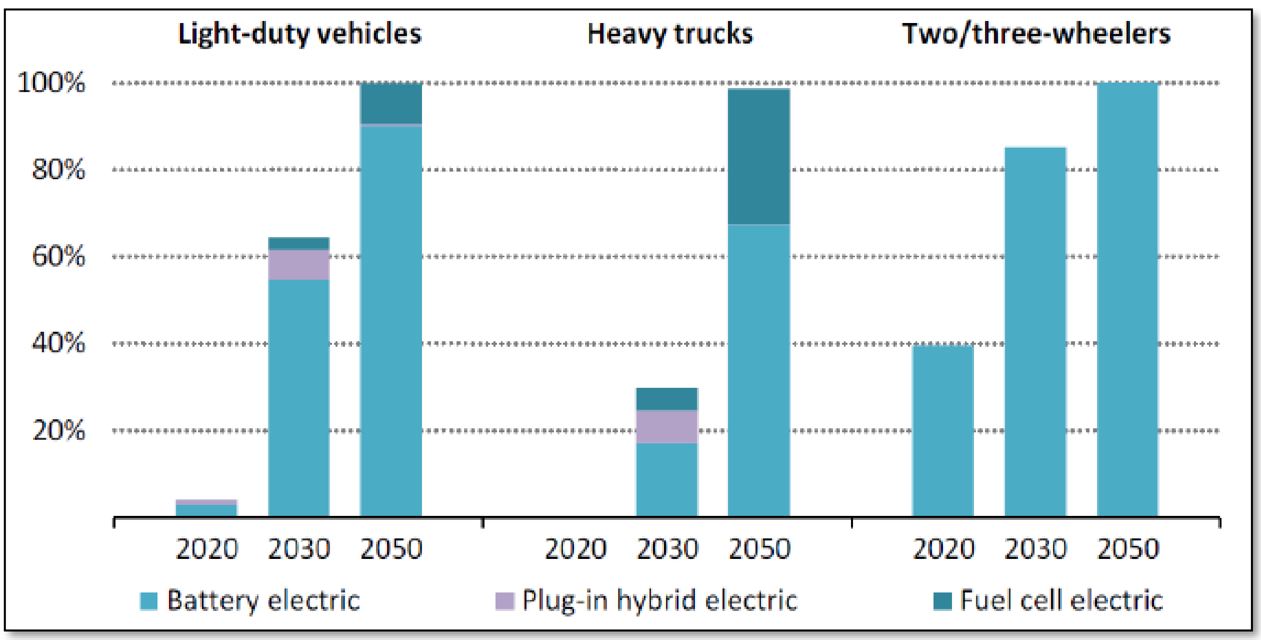
**Light-duty plug-in electric vehicle role – in Net Zero Emission scenario**

To move toward the deep decorbanisation goal as per net zero emission scenario analysis,

- Passenger EVs need to be 61% of global light duty vehicle sale by 2030

- developed countries this has be around 100% new market share between 2030 and 2035 (IEA, 2021). As per net zero emission (NZE) scenario PHEVs about 5% of 2030 sales. In moving forward by 2050 PHEV sales is negligible. The assumption considered for NZE is the massive scale-up of the renewable source of electricity and quadrupling the capacity with respective installed capacity of solar and wind from 2020 to 20230 level.

**Figure 2.11 Net zero emission scenario assumptions on penetration of EV (IEA 2021)**



### 2.14.4 Heavy-duty plug-in electric vehicles

**Technology background**

The development in the area of the "Truck and Buses" for deep decorbanisation is lacking and not on track to meet the greenhouse gas emission level target (IEA, 2021). This is because lack of progress in vehicle efficiency. There are even challenges for categorisation on truck and buses. The trucks are categories as light-duty, heavy-duty trucks and medium-duty trucks. The busses categorisation as per passenger seat capacities.

There is comparatively less focus on heavy duty freight truck policies compare to the light-duty freight truck despite these are continued contributing in global GHG emissions. The heavy-duty freight truck can be further sub-categories, including passenger buses, medium- and heavy-duty freight trucks to bring more focus. In truck category there is other diverse categorisation like "vocational" vehicles (used for garbage, bucket), concrete mixer and sweeper trucks. The trucks have spread of application and categorisation. The greenhouse emission from heavy truck category is about 55%, 27% from medium truck and 18% from (IEA, 2021).

The challenges express in review for deep decorbanisation of heavy-duty truck vehicles is that sector may be more complicated and diverse than passenger electrical vehicle. Specifically, there is a wider range of vehicle types, loads and usage profiles, such as short haul versus long-haul freight and various vocational uses for trucks. As per the studies the more appropriate applications of battery electric vehicles (BEVs) are as below.

- for shorter distance run vehicles
- goods delivery trucks
- corporation garbage trucks
- short-haul freight for goods for other purpose

But for fuel cell electric vehicles (FCEVs) most suited application is long-haul trucks (IEA 2021; Axsen, Hammond and Kjeang, 2020; Liimatainen et al., 2019; Moultak , Lutsey and Hall, 2017).

As per electrical vehicle range analysis for current model and announce model (2020 to 2023), the range varies and example of is as below (IEA, 2021):

• Buses – 50 to 650 km (290km average)

• Heavy freight trucks – 100 to 700km (400km average) and

• Medium freight trucks – 100 to 450km (275km average).

As per 2021 data the difference electrical bus and truck model are available for sales.

1. about 245 different electric bus models
2. around 120 electric medium-duty trucks
3. 50 electric heavy-duty truck models (IEA, 2021).

As per prediction in the US from 2020-2023 the heavy-duty truck models are expected to grow 2.5 times. The around 20 manufacturers are planning for additional heavy-duty BEV models (like Volvo, Daimler (Freightliner), Nikola, MAN, Scania and Tesla).

There is challenge in this sector is largest and heavy-duty vehicle required higher capacities of the batteries and higher power charging. There are two important potential solution for this.

1. "Mega chargers' developments" – For quickly charging up of the large batteries of long-haul trucking at rate of 1 megawatt (MW). There is development going om for the mega charger development. The stakeholder working on the mega charger include CHAdeMO22 and China Electricity Council (IEA, 2021).
2. "Overhead catenaries" – this to charge the heavy-duty vehicle while in motion. use to charge heavy-duty vehicles while in motion. This is specially can be used for long-haul trucking operations (Bock S et al., 2021). There are projects in some countries to test these solutions
    i. In the Germany (SPIL Powerlines Germany and Siemens Mobility),
    ii. In the UK (3.4-20km stretches of catenaries) (IEA, 2021).

Heavy-duty plug-in electric vehicles - market penetration Electric Bus

The penetration of the electric bus varies widely by the categories and the countries. The electric bus contribution is around 85,000. This 3% of the global buses sales which rerestarted in 20202 (ICCT, 2021). Th contribution of this as per country is as below,

i. China 78,000

ii. Europe 2100 of total

iii. North America 580 of total

iv. India and other countries remaining (IEA, 2021)

So total global stock of electrical bus is 600,000 electric buses and country wise contribution is as below.

The countries wise electrical buses market share is as below

- Netherlands (69%)
- China (23%)
- Norway (17%)
- Sweden (10%)
- UK (6%) (ICCT, 2021a).
- China and the EU, including Canada (1.7%),
- US (0.6%),
- India (0.4%)
- Japan (0.1%).

As per this data electrical Truck and bus contribution is negligible in developing countries.

Heavy-duty electric trucks:

In 2020 the global heavy-duty truck market sale reached 7,400 (w.r.t. 2019 10% increase). The total global stock is 31,000 electric trucks (IEA, 2021). This is less than 0.1% of total global ICEs heavy truck sales (ICCT, 2021). The distribution of the 7400 is in China (6,700), in Europe (450), US (240) and remaining with rest of the countries (IEA, 2021). The electrical truck and bus sales in other countries than China, Europe and US are negligible.

•Medium-duty trucks: The sales in 20202 increases by 0.5% of total medium truck in 2020. In this Germany is new market with increase in share 6.5 %, Netherlands 3.4%, UK 1.3% and China 1.3% (ICCT, 2021).

**Heavy-duty plug-in electric vehicles - Carbon impacts**

As per study the total greenhouse gas emission impact of the electrical vehicle (light, medium and heavy-duty truck) and varies with the sources of electricity and usage patterns. The GHG emission impact has been studied in 3 developed countries. Below are the country wise results.

• Canada: heavy-duty freight GHG emissions 34-98% (compared to diesel as per WTW) for short- and long-haul applications. Since drive cycle is better and electricity source are less carbon intensive (Axsen, Crawford and Lajevardi, 2019).

• US: GHG emission reduction 63% with clear grid technology. As per life cycle assessment (LCA GHG emissions) for manufacturing batteries, charging stations BEVs only perform slightly better than diesel trucks (Sen, Ercan and Tatari, 2017).

• Norway: greenhouse gas (GHG) emissions 68%. This is including the vehicle and drivetrain manufacturing (Booto, Aamodt and Hancke, 2021).

The magnitude of greenhouse gas reduction of electrical vehicle is less in China, India and other developing countries. Due to use of the carbon intensive electricity generation source.

**Heavy-duty plug-in electric vehicles - role in Net Zero Emission scenario**

**As per NZE scenario**,

i. The global heavy duty truck sales contribute 25 % by 2030, 50% by 2035 and around 70% by 2050.
ii. The stock of the electrical bus reaches up to 60% by 2030 and 100% by 2050.
iii. In light duty categories plug in hybrid sale 5% by 2030 (IEA, 2020) and eligible sale in 2050. By this time PHEVs would be fully replaced by BEVs and FCEVs.

Heavy-duty plug-in electric vehicles - opportunities for plug-in electric vehicles

There are socio-economic opportunities to develop the electric vehicle market. Three opportunities are as below.

i. The countries like Norway, US (California) and Canada (Quebec)) (Bernstein et al., 2022) has demonstrated the strong electrical vehicle growth strong widely used. The EV sales in these countries' regions are driven by combinations of incentives, strong regulations and pricing mechanisms. The other global countries would like to increase sales by emulating these kind of policies (Axsen, Melton and Moawad, 2020). The heavy-duty vehicle sector can use these proven policies to develop electrical vehicle market and reduce greenhouse emission (Axsen, Hammond and Kjeang, 2020).

ii. The total cost of ownership of electrical vehicle is 30% less in comparison with conventional vehicle (Ayetor et al., 2021). This can be taken as opportunities to increase electrical vehicle to align increase vehicle ownership trend and reduce greenhouse gas emission (Rafiu, Daniels and Sovacool, 2022). There is opportunity to increase Two- and three-wheelers sales with low-cost electrification, in this less impact to electricity grids due to smaller batteries (IEA, 2021).

iii. The smart charging program utilisation which will help to optimize the electrical vehicle charging to better complement the electricity grid. This will help to improve greenhouse gas reduction to complement the availability of renewable energy sources. As per studies this program will help to reduce the GHG emissions of passenger electrical vehicle (20% in Beijing at 2022 and 50% in Germany) (Kacperski et al., 2022). The Smart charging programs can help to reduce the electricity prices (Axsen et al., 2018). The more research are needed on battery "second use". Since the 2$^{nd}$ life of batteries are no longer suitable for vehicle usage might still provide a helpful load management service to electrical grids.

### 2.14.5 Fuel cell electric vehicles (FCEVs)

**Technology background**

The Hydrogen is a combustible gas and used in a variety of chemical and refinery processes. The major end-user application of the same are direct process heating and transportation. Tits possible to power the ICE vehicle with hydrogen. In present major focus is on the fuel cell electric vehicles (FCEVs). In this process the fuel cells use to convert hydrogen to electricity. This generated electricity powered the vehicle via electric motor. The FCEVs emit no tailpipe emissions. But the well to wheel (WTW) greenhouse (GHG) impact depends on the source of energy used to produce the hydrogen. The common terminology used to produce hydrogen are as follows (Bataille and Li, 2021):

i. Black hydrogen - The most commonly used and produced from coal via steam methane reformation.

ii. Grey hydrogen – This is produced from natural gas via steam methane reformation. This tends to have the lowest cost production method.

iii. Blue hydrogen – This is produced from natural gas as with grey hydrogen. This is used carbon capture and storage (CCS) to capture approximately 90% of the CO2 emissions stored underground.

iv. Green hydrogen – This is produced with electrolysis to transform the electricity produced by renewable sources (electricity generated by wind, solar or other renewable sources). This can be utilised excess intermittent renewable energy that might be costly at this stage (Bataille and Li, 2021).

As per IEA NZE scenario, all forms of hydrogen will make up 28% of transport fuels in 2050 and green hydrogen will increase from 5% of hydrogen sources in 2020 to 63% in 2050 (IEA, 2021).

**Fuel cell electric vehicles (FCEVs) - light-duty fuel cell electric vehicles**

The Fuel cell electrical vehicle (FCEV) are considered to be a ZEV (net zero emission vehicle). Since there are no tailpipe emissions. In this vehicle the hydrogen is stored on board and conversion of the electricity happen by using fuel-cell, which powers an electric motor. The few available FCEVs model in are Honda Clarity, Toyota Mirai and Hyundai Nexo. The driving range for this is around 500-700km and take several minutes to refuel. The Toyota and Hyundai are remained committed to FCEVs (For example, Toyota planning to release hydrogen-powered versions of the Prius and Corolla in 2023).

The few technology barriers for FCEVs at present by aggressive work go on in this area. At present FCEV at nascent stage and due to this manufacturing costs and purchase prices high, with double the total cost of ownership (compared to conventional ICE vehicles) (Hesary and Li, 2022; Whiston et al., 2022). The substantial development happened from 2008 to 2020 and due to this the cost of FCEV fuel cells has decreased by 70% (IEA, 2021). Even though FCEVs are getting benefit from the decreasing costs of advanced batteries and electric motors.

The FCEVs need to be fuelled at hydrogen fuelling stations. In 2020 540 hydrogen fuelling stations were available globally. This is a 15% increase with respect to previous year (IEA, 2021). The hydrogen fuel stations are in Europe, Japan, China, the US, Korea and few in other countries. As per IEA NZE assumption this fuelling station will an increase to 18,000 stations by 2030 and 90,000 by 2050.

**Fuel cell electric vehicles (FCEVs) - Market penetration**

In 20214 FCEVs first became commercially available in market. By 2020 the global stock of light-duty FCEVs was about 25,000 vehicles. The distribution of this is 29% in Korea, 27% in the US, 24% in China and rest mostly in Japan and Europe (IEA, 2021). The FCEV sales other than these countries are negligible. In 2020, FCEV stock double with respect to 2019 due Korea increase sales (IEA, 2021).

**Fuel cell electric vehicles (FCEVs) - carbon impacts**

The greenhouse gas impact due to FCEV depends on the used hydrogen source. As per ICCT's analysis medium-sized light duty FCEVs used in 2020 reduce GHG emissions by 26-40% compared to conventional ICE (gasoline) vehicles across the tested regions (North America, Europe, China and India). At that time the hydrogen dominated by “grey” hydrogen (ICCT, 2021b). As per analysis by using green hydrogen GHG emissions are 76%–80% lower than conventional ICE gasoline vehicles (LCA analysis). As per LCA emissions of FCEV and BEVs, the FCEV are emission more compared to BEV with same renewable electricity. The hydrogen powered FCEVs are energy-intensive nature due to energy intensive conversion of the renewable electricity to hydrogen and then back to electricity (ICCT, 2021).

**Fuel cell electric vehicles (FCEVs) - role in Net Zero Emission scenario**

The NZE scenario assumes that FCEVs make up a few percent of light-duty sales in 2030 and up to 10% by 2050 (IEA, 2021).

Fuel cell electric vehicles (FCEVs) heavy duty vehicles - technology background.

The Heavy-duty FCEVs as well as the light duty models have similar needs for hydrogen production and refuelling infrastructure. As per studies FCEVs might be better suited for heavy-duty applications. Because FCEVs can store more energy for heavy-duty vehicles than BEVs. As per IEA NZE assumes that FCEVs will be more competitive than BEVs for heavy trucks with daily ranges that exceed 450km (IEA, 2021). The FCEV heavy duty (trucks and buses) total cost of ownership (TOC) is calculated as 3 time compared to current conventional ICE technologies truck (Hesary and Li, 2022). The FCEV trucks refuelling time is 8-20 min include for 400 Km range cargo truck (example Hyundai Xcient). The Daimler, Nikola, Renault, Volvo and other have announce the heavy-duty model (IEA, 2021). The FCEV hydrogen fuelling infrastructure was limited in 2002 about 540 fuelling stations globally.

**Fuel cell electric vehicles (FCEVs) heavy duty vehicles - market penetration**

In 2020 FCEV market were 3500 truck and 5500 FCEV buses on the road. The major contribution of market is in China (94% buses and 99% trucks) (IEA, 2021).

Fuel cell electric vehicles (FCEVs) heavy duty vehicles Carbon impacts.

The Heavy-duty FCEVs and light can offer similar climate benefits like light-duty electrical vehicle, especially if green hydrogen is used. As per WTW analysis heavy-duty vehicles powered by grey hydrogen can range from a 4% increase to a 65% decrease in GHG emissions and this subjected to drive cycle and drivetrain technology (Axsen, Crawford and Lajevardi, 2019). The FCEV technology will help for deep cut (89-97%) in greenhouse gas emission by usage of green hydrogen compared to current ICE technology heavy diesel trucks (Axsen, Crawford and Lajevardi, 2019). The initial study in Norway indicated that 48% greenhouse gas emission can be reduced in lifecycle. This is including GHG from drivetrain manufacturing and from vehicle (Booto, Aamodt and Hancke, 2021). The study concluded China indicates that FCEV powered by green hydrogen (heavy trucks and buses) can reduce around 60-77% WTW emission. (Li and Hesary, 2022).

**Fuel cell electric vehicles (FCEVs) heavy duty vehicles- role in Net Zero Emissions scenario**

As per studies Heavy-duty FCEVs are expected to play important role for decarbonization in future years. As per IEA NZE scenario, FCEVs sales 5% in 2030 and 30% in 2050 for heavy duty vehicle. The deep carbonisation study indicated requirement of the split between split between BEVs and FCEVs for heavy-duty vehicle globally. The Canada base 2 different modelling studies results indicated to 80% GHG reduction in the transport sector by 20250 required split implementation of hydrogen and electricity-powered heavy-duty vehicles (Axsen, Hammond and Kjeang, 2020; Axsen and Lepitzki, 2018). In these new sales heavy duty freight truck are 74% in 2050 (Axsen and Lepitzki, 2018).

Fuel cell electric vehicles (FCEVs) heavy duty vehicles Opportunities

The major barriers for the FCEV are as below.

1. high purchase price
2. lack of refuelling infrastructure.

In China FCEV sales increase is dependent purchase subsidies (Hesary and Li, 2022). The purchase subsidies can help in the short-term and long-term success need to drastically increase production levels and technology breakthroughs to reduce manufacturing costs.

There is some optimism point for future progress

The international alliances will help to boost R and D (Hesary and Li, 2022). The FCEV cost reduction required technology break through, R and D alliances for collaborative integrated research increase the performance and affordability, FCEV components and manufacturing cost reduction (Ahluwalia et al., 2021). The study indicated that while future is highly uncertain still hydrogen experts projecting positive forecast trends for FCEVs. As per this there will be a three-fold decrease in fuel-cell production costs from 2020-2035 (Lima et al., 2022). The ZEV supportive policies include incentives allocation for FCEV like BEV will help to boost FCEVs. This support is including purchase subsidies, support for fuelling infrastructure development, regulations, private sector to invest in FCEVs and green hydrogen.

#### 2.14.6 Advanced Biofuels

**Biofuel background**

The Biodiesel can be used as a blend or replace diesel. The developing countries has produced approximately 40% of liquid biofuel globally from 2013 to 2019 (Masron and Subramaniam, 2021). The biofuel fuel consumption transport can be 59% with blending or replacement of gasoline (IEA, 2021). At present the liquid biofuel used is in transport by blending in small % in gasoline or diesel (at a rate of 5% to 10% or less) (IEA, 2021).

In flex-fuel vehicles higher biofuel blends (E85 blend include 85% ethanol) or in some cases a pure biofuel (unblended) is getting used. The “Drop-in” fuels are under development to use in high shares or even unblended in engines designed for gasoline or diesel, without doing modification in engine. The liquid biofuel is getting manufactured with variety of feedstocks. The greenhouse gas emissions and sustainability impacts are varying widely with respect to the feedstock. The last two decade the energy policies has supported biofuel blending, without distinguishing between feedstock sources.

In the use corn feedstock is used to reduce petroleum. But this is not reducing lifecycle GHG emissions compare to gasoline (Farrell et al., 2006). There is a major distinction are getting crease for feedback in conventional and advanced biofuel. The conventional biofuels use food-based crops feedstock and compete for land with food. The greenhouse gas emission impact for variety of feedback change. It is including slight or negligible reductions or even substantial increases. The 93% of liquid biofuel were produced from conventional food-based crops (soybeans, corn and sugarcane) as per 2020 data (IEA, 2021). The development has happened in advance bioenergy as fuels and important point about this are as below (IEA, 2021)

i. Significant lifecycle greenhouse gas (GHG) reductions compared to the fossil fuels which they are replacing

ii. produced from non-food crop feedstocks

iii. It should not directly compete for land with food or feed crops

iv. Is should not cause other adverse sustainability or biodiversity impacts.

The feedstocks for advanced biofuels

1. waste streams, agriculture and industry residues
2. woody residues and woody crops
3. other feedstocks which do not compete with food (IEA, 2021).

The carbon capture storage (CCS) method produced biofuel will have 10% share of bioenergy consumption in 2025. The biofuel processing has cost challenge and development going on in this area. The advanced biofuels are evolving to address current biofuel technical concern. The current process is double to triple to those fossil fuel prices but could decline by one-quarter or more by 2030 (IEA, 2020). The biofuel produced from advanced feedstocks are only 7% of biofuels produced in 2020 (biofuel produced from cooking oil and waste animal fat). As pe the NZE scenario targets an increase to 45% share of biofuels by 2030.

The global demand for liquid biofuels from 2010 to 2019 has increased by 5%. In 2020 biofuels contribution was only 3% global transport fuels. As per current assessment done by IEA biofuel development is “not on track” with respect to decarbonization goals (IEA, 2021).

As per NZE scenario, 14 % consumption increase of biofuel from 2020 to 20230. The biofuel blending with fossil fuel will be 15% 2030 and 41 in 2050 (IEA, 2021). As per prediction biofuel is going to play limited role in road transportation past 2030. Since as per NZE scenario BEVs and FCEVs are going to dominate. This advance biofuel would be use for aviation and shipping. Even biofuels usage will be about 10% for heavy-duty trucks in 2050.

**Advanced ethanol - background and market penetration**

As process ethanol is produced by fermenting biomass. The feedback used to manufacture the conventional ethanol is food energy crops such as corn, wheat, sugar beet, sugarcane, barley and rye. The below are the feedback stock to manufacture the ethanol.

1. In US, China, Argentina, Bulgaria, India and several African countries - mostly produced from corn (Masron and Subramaniam, 2021).
2. In Europe - split between corn (38% of the ethanol mix), wheat (30%) and sugar beet (19%) (ICCT, 2021b).
3. Bolivia, Uruguay, Mexico and Brazil - sugarcane (Masron and Subramaniam, 2021).
4. Southeast Asian countries such as Thailand and the Philippines - cassava and sugar cane (Kumar et al., 2013).

The Brazil is one of the leading biofuel manufacturing at present (Masron and Subramaniam, 2021). The fibrous material feedstocks include cellulose and hemicellulose are abundantly available such as woody raw materials, wheat straw and agricultural residues (ICCT and IEA, 2021). The production of advanced ethanol is at early development stages and relatively negligible global market penetration due to the high cost. The advance ethanol include wheat straw and Europe can achieve 4% in 2020 by this. This is expected to increase to 13% in 2030 (ICCT, 2021). The ethanol blending into gasoline can be done irrespective id the feedstock used to manufacture the ethanol. The country wise % ethanol blending as below

i. Europe and China -5%

ii. US and Canada (10% (and now up to 15%)

iii. India 5-20% (ICCT, 2021b).

The blending of ethanal up to 85% (E85) can be done with flex-fuel vehicles. This is existed in significant number in a few countries such as

1. US (21 million vehicles),
2. Canada (1.6 million),
3. Brazil (30 million)
4. Sweden.

The many of these flex-fuel vehicles are refuelled mostly or exclusively with conventional gasoline rather than 85% blend (E85 blend). The ethanol in gasoline and flex-fuel vehicles give lower fuel economy than gasoline. The major reasons for this are as below.

i) Lower energy density of ethanol with respect gasoline and

ii) The gasoline vehicle optimises to run on gasoline but not for ethanol

Bio-fuel - carbon impacts

The greenhouse gas impact of ethanol by lifecycle assessment (LCA) vary substantially by feedstock, production method, region and agriculture. The calculation of lifecycle impacts is uncertain as well, especially the incorporation and quantification of indirect land-use change (ILUC). In US and China ethanol is dominated by corn feedstocks. This ethanol is helping for 18-22% greenhouse gas reduction (ICCT, 2021). Analysis of light-duty vehicles in Europe shows that the GHG impacts of conventional ethanol can vary by feedstock,

with a 24% reduction in GHG emissions from corn,

54% from sugar beets and

56% from sugar cane.

wheat-based ethanol can range from a 4% increase to 8% reduction in GHG emissions, barley/rye causes an 11% increase in emissions. Wheat straw, an advanced ethanol feedstock, can yield 81% reductions in LCA GHG emissions. At present there is less analysis conducted on the lifecycle impacts of biofuels produced in developing countries (Itsubo et al., 2021). The ethanol produced from corn in Argentina reduce greenhouse gas emission by 37% as per well to wheel method. But ethanol produced from switchgrass can reduce greenhouse gas emission by 66-74% (Brazil, Colombia, Argentina and Guatemal).

**Bio-fuel - role in net zero emissions scenario**

As per NZE scenario, total ethanol consumption is assumed to increase by 38% from 2020 to 2030 but from 2040 to 20240 going to contract (IEA, 2021). The increase in advance ethanol proportion will help for net zero emission and demand for ethanol <0.1% in 2020 to 27%) in 2030. The over and above this 23% is assumed to be conventional ethanol with CCS in 2030, at a magnitude that stays consistent until 2050.

**Advanced biodiesel - Background and market penetration**

The conventional biodiesel is produced using the fatty acid and methyl esters (FAME) route (transesterification) from food oil crops, such as rapeseed, palm, soybean, flax, sunflower, mustard and coconut. The proportion of feedstocks vary by region; in Europe, the biodiesel mix includes 52% rapeseed oil and 20% palm oil (ICCT, 2021). Biodiesel is largely produced from palm and soybean oil in Brazil, Argentina, Uruguay and Indonesia (Masron and Subramaniam, 2021). Indonesia and Malaysia are the two largest producers of palm oil and both countries are aiming to increase their biodiesel production.

Advanced biodiesel uses non-food feedstocks such as waste cooking oil, fish oil, algae oil, animal fats and potentially cellulosic material as well. The cellulosic material required advance production methos like Fischer-Tropsch to manufacture advance biodiesel. In Europe’s 2020 biodiesel feedstock include 17% mixed of used cooking oil and 5% cooking fats (ICCT, 2021). The Biodiesel can be blended into diesel to use in diesel vehicles with no engine modification. The higher % blend is compromised to the performance. The common blending rates as off now are 7% in Europe and 5% in India (ICCT, 2021). In the US biodiesel blending rates are 2%, 5% and 20% and 100% and this include warranties for many vehicles. The blending more than 20% will not cover warranties.

The use of 100% biodiesel in vehicle requires engine modifications. But HDRD (Hydrogenation-derived renewable diesel) is emerging as a form of "drop-in" diesel. This can be produced by using fat or oil-based biodiesel feedstocks and maintain a chemical composition close to identical to diesel. This will allow to use 100% blends with no vehicle engine modifications. The HDRD production has developed in Singapore and export to the US and Canada majorly.

**Advanced biodiesel carbon impacts**

The lifecycle impact of greenhouse gas emission is varying with biodiesel feedstock. As per of analysis in Europe is as below.

i. rapeseed oil (22% increase in GHG emissions intensity)

ii. palm oil (180% increase), soybean oil (120% increase)

iii. sunflower oil (11% increase) (ICCT, 2021b).

But as per analysis, advanced biodiesel reduces GHG emissions by 85-92%. Which made from cooking oil, animal fats and other residual sources. The well to wheel (WTW) study of Latin America indicates that, soybean oil-based biodiesel can reduce GHG emissions as below.

i. 79% in Argentina

ii. 68% in Brazil

iii. 84% in Colombia (palm-oil based biodiesel)

**Advanced biodiesel - role in net zero Emissions scenario**

As per NZE scenario analysis biodiesel play important role in lowering heavy duty truck emission in 2020s before 2030 – 20240 BEVs and FCEVs dominate. The biodiesel consumption expected 2020 – 2020 is expected to increase by over 3.5 times. Amon complete biodiesel the contribution of the advance biodiesel is assumed to go from 16% in 2020 to 58% in 2030 and over 90% of biodiesel in 2050 (IEA, 2021). As per Canada deep decorbanisation modelling study biofuels would fulfil 43% freight transportation of energy demand in 2050. This greenhouse gas reduction target is with ambitious climate policies including a low-carbon fuel standard on place (Axsen and Lepitzki, 2018).

**Advanced biofuels - opportunities**

There is possibility to produce low carbon form of ethanol. There is opportunity to develop low carbon form of the ethanol and biofuels. For this policymaker has to send green signal for research and development focus on advanced low carbon and biofuel technology. There is potential to develop lower cost production methos low-carbon biofuels, HDRD, including cellulosic ethanol and biofuel with CCS (BECCS). The region like Latin America and Africa have potential for further development of low-carbon biofuels which help to achieve various sustainability goals.

These are helping in reduction of the lifecycle carbon intensity and supporting the current policies in that direction. The policies such as,

1. Europe's "Fit for 55"
2. California's low-carbon fuel standard (LCFS)
3. the US Renewable Fuel Standard,
4. Canada's Clean Fuel Standard (CFS)
5. India's ethanol blending mandate
6. China's latest 5-year plan
7. Latin America's Renova-Bio (IEA, 2021).

As per analysis these policies can help to drive reductions in carbon intensity. As per the low carbon fuel standard in California, the lifecycle of the carbon intensity of ethanol used decline by the 29% and carbon intensity of the biodiesel fell by 36% (from 2011-2019) (California Air Resources Board, 2020). The supporting point for the is that higher level support from citizens among transport climate policies (Axsen, Long and Kitt, 2020; Axsen, Jaccard and Rhodes, 2017). The integration of policies and comprehensive coverage will help to avoid leakage and shuffling effect. The leakage when low carbon fuel sends to regulated regions, or while sent to unregulated regions, reducing any net global GHG benefit from policy (Bento et al., 2015).

### 2.14.7 Shared mobility

The broad concept of the Shared mobility has split as below.

i. car-sharing (the sharing of vehicles, bike and scooter)

ii. ride-hailing (car-pooling and ride sharing)

The numerous studies indicated that enormous transitions in fuels and efficiency needed to meet ZEV along with that "behaviour changes" is also needed (Boig et al., 2021; IEA, 2021). In the transportation, reduction in the % of the vehicle ownership and achieve less vehicle kilometre refer. As per NZE scenario behaviour changes account for 4% of cumulative emissions reductions by 2050. There is shift about 20-50% of passenger trip in the large cities from single occupancy passenger to shared mobility and use of active public transportation and in 2030, 45% shift expected (IEA, 2021). In 20250 behavioural changes will reduce car ownership in 2050 and of single-car households fall from 35% to 20% contribution and two-car households fall 13% to 5% (IEA, 2021).

The several existing and emerging forms of the shared mobility are there and contributing major role in deep decorbanisation.

i. ride-hailing
ii. car-sharing,
iii. micro mobility
iv. Mobility-as-a-Service (MaaS).

At present net greenhouse gas emission (GHG) impacts of these modes of travel is largely variable and unclear. These are dependent on the below factors.

i) replaced mode of transport carbon intensity
ii) vehicle ownership and
iii) overall vehicle per kilometre travel (VKM).

The researchers have studied the importance of "pooling". In this a shared mobility mode is use vehicles for ride-hailing and car-sharing. The greenhouse gas emission (GHG) reduction there when vehicle used for trips that "pool" multiple passengers to increase overall vehicle occupancy (Sperling, 2018).

**Ride-hailing**

The ride-hailing is an app-based platform. There are the service providers like Uber and Lyft well-known in most countries (Shaheen, 2018). This is important to distinguish between:

i. Trip for individual or with friends/acquaintances

ii. Trip shared among two or more strangers, aside from the driver. This is generally required multiple pick-up and drop-off points.

The ride-hailing is entered in market around 2010. In Europe most of countries ride-hailing penetration is slow. This trend is increasing in China and reported highest record than the US. The ride-hailing is having a positive and negative impacts and intensity of that change with countries (Hisashi and Shah, 2021).

The environmental impacts of ride-hailing are generally unclear. It's difficult to identify the orders of impacts. The studies in the USA indicated this would reduce car-ownership (Rodier, 2018) special for frequent users of ride-hailing (Wang et al., 2021). The other studies in the US and China indicate indicated that ride-hailing can increase overall (VKM) vehicle kilometre travel (Schaller, 2017). The ride-hailing usage typically substitutes for public transit, active travel and taxi usage (Clewlow and Mishra, 2017; Shaheen, 2018; Shi et al., 2021).

The greenhouse gas emission net impacts are but as per studies the impact in USA has slightly increased (Rodier, 2018). The simulation study of Paris, France indicated that ride-hailing can lead to GHG reductions about two-thirds or more of the benefit and cancelled out by rebound effects (Boutueil et al., 2019). The rebounds occur when users switching away due to reduction in the travel costs and travel times, driving longer distances and relocating their residences further from the urban centre.

**Car-sharing**

In car sharing the travellers are paying for service based on hourly or milage base or both. In this user use the vehicle and return it somewhere location (Cervero et al., 2007). Parking can be station-based or free-floating and trip structure can be one-way or two-way (Dowlatabadi et al., 2019). Peer-to-peer (P2P) car-sharing is an emerging form that allows individuals to rent out their personal vehicles (Georen et al., 2009).

From 2006 to 2018, the number of global members has increased from around 350,000 to over 30 million and the number of car-share vehicles has increased from around 11,000 to almost 200,000 (Shaheen and Cohen, 2020). Global membership increased by a factor of 10 from 2014 to 2018 (Shaheen and Cohen, 2020). As of 2020, carsharing programs have been documented in 47 countries, with over two-thirds of members in Asia and about 20% in Europe (Shaheen and Cohen, 2020).

Some counties like Brazil, Maxico, Turkey part of region support for car sharing program. The net societal impacts of car-sharing programs are uncertain, though it is often considered as a pathway to reduce vehicle ownership (Baptista, Melo and Rolim Baptista, 2014; Firnkorn and Müller, 2011). One study of 11 European cities finds that car ownership was reduced in each city due to the car-share program, where each car-share vehicle can replace several or up to 20 private cars (Firnkorn and Muller, 2011). An earlier US-based car-share study indicates that participation in a car-share program reduced the average number of cars per household from 0.47 to 0.24 (Creutzig et al., 2010).

**Shared micro-mobility**

The micro-mobility follows similar principles to car-sharing, but includes the sharing of bikes, e-bikes and e-scooters. The shared micro-mobility program has variation element like dock less area, no designated parking or storage space. While shared micro-mobility was largely suspended during Covid-19 lockdowns, since then 270 cities have relaunched operations services (IEA, 2021). The globally 650 cities are register the micro mobility service (IEA, 2021). Shared e-scooters have over-taken shared dock less bikes in Europe, Central Asia and North America, though shared bikes are more popular in East Asia and Pacific countries (IEA, 2021). Average trip distances on e-scooters have increased by 25% compared to before the pandemic (IEA, 2021). There has also been a recent increase in the use of swappable batteries, which allows operators to quickly replace depleted e-scooters and e-bikes with fully charged batteries.

Again, the emergence of micro-mobility holds the potential for GHG emission reductions if it is replacing higher-carbon modes and supporting, rather than displacing, public transit and active travel (Bucher et al., 2019). Bike-sharing is hoped to inspire more travellers to take up active-travel, though again, the evidence is unclear (Hosford et al., 2018). As with car-sharing, the important question is: what mode is being replaced? Also, one study considers lifecycle emissions from micro-mobility, including vehicle, fuel, infrastructure and operational services. The authors find that shared e-scooters and shared e-bikes can emit more gCO2 per passenger km travelled (PKM) than public transit, personal bikes and privately owned e-bikes and e-scooters (Reck et al., 2022). The greenhouse gas emission benefits or impacts are varying by region. Some studies noted that the greenhouse gas emission reduction by micro-mobility is not substantial. As key examples, mostly from the US:

• US - a recent statistical study of US travel data finds that bike-share usage is not associated with an increase or decrease in travel GHG emissions (Bian et al., 2022).

• Nashville, US - bus ridership reduction by 0.08% with share e-scoters on weekday (Brakewood et al., 2021)

• Chicago, US: shared e-scooters have reduced bike-sharing usage by 20% (Cherry C et al., 2021).

• Washington, DC, US: shared e-scooters are often substituting for transit and bikeshare usage due to time savings. Though, in some cases, e-scooters can complement transit, where 10% of e-scooter trips connected with the city's Metrorail system (Cherry C et al., 2021).

• Zurich, Switzerland: e-scooters could increase $gCO_2$ per PKM by 92%, when accounting for the modes they substitute for.

More research is needed to assess the current and future potential impacts of micro-mobility, especially in developing countries.

**Mobility-as-a-Service**

The concept of Mobility-as-a-Service (MaaS) aims to advance the potential complementarity of public transit and shared mobility. The hope is to increase the usage of both modes and ultimately to reduce private vehicle ownership and usage (Matyas and Kamargianni, 2018). MaaS can be defined as defined as follows: with a single payment and streamlined user experience, travellers can get from origin to destination through some combination of public transit, ride-hailing, car-share and/or micro-mobility modes. The Public transportation or transit lines are backbone of a MaaS system. But the first and last miles could help to mitigate problem associated with commuter rail or main bus service systems (Cherry C.R et al., 2021). The term MaaS is thought to have been coined in 2014 in Finland and is now being explored in pilots around the world, notably Europe (Molinares and Palomares, 2020). The International MaaS Alliance maintains a list of dozens of MaaS initiatives and projects across Europe, including Sweden, the UK, Germany, France and Spain, as well as Canada, the US, Taiwan, Singapore and Australia.40

A 2020 review of 59 MaaS studies indicates that evidence regarding its costs and benefits are uncertain (Molinares and Palomares, 2020). The reduction in carbon emission by shared mobility or MaaS can be improve by increasing use of the low-carbon modes of travel instead of high carbon intensive modes. The other important point of reduction on carbon emission is active travel, share mobility in place of the single user travel. As per previous studies, MaaS could help to reduce private car usage and reduce greenhouse gas emission. But the reduction in greenhouse gas emission have limited proof (Labee, Liao and Rasouli, 2022). The one of the pilot study Australia (Sydney) (Australia) on vehicle travel (VKM) of mobility as a service (MaaS) users dropped over time even though many participants continued to use vehicles (cars) (Hensher, Ho C

Q, Reck, 2021). As per simulations studies data from Amsterdam at the Netherlands shown below greenhouse gas emissions reduction.

- conservative scenario 3-4%
- balance scenario 4-19%
- optimistic scenario 43-54% (Labee et al., 2022).

The focused on MaaS in developing countries is not there. The study in Philippines (Manila) noted that 84% of respondents are ready to use MaaS app and 61% of users shown interest to use public transport if MaaS available (Bigotte et al., 2022).

**Opportunities for shared mobility**

The good opportunity to reduce the greenhouse gas (GHG) reduction is to more important to on design and research. The main avenue for decarbonization is to make sure that uptake of the shared mobility mode is substituting for higher carbon modes of travel and reducing private vehicle ownership and usage. For the sharing of light-duty vehicles via ride-hailing and car-sharing, there needs to be more push and support for pooled usage (Sperling, 2018). The use of shared vehicle is electric help to reduce the emission and extend the carbon benefit. The concern stakeholders are proposing policy deployment that incentivize the to use electrical vehicles for the ride hailing or (Bernard, Hall and Nicholas, 2021). The shared mobility modes required further development and this can be done with legislative benefit and facility uptake to improve GHG benefits (example - Finland's Act on Transport Services).

Finally, improved consumer research can help to understand how to attract more consumers and different consumer groups, to shared mobility programs. As one example, a survey in Ghana found that car-share programs are more attractive to travellers with higher pro-environmental and pro-technology attitudes, as well as those dissatisfied with existing transit services (Acheampong and Siiba, 2020)

### 2.14.8 Fully automated vehicles

This report uses the term fully automated vehicles (FAVs), while acknowledging that the terms autonomous, self-driving and driverless vehicles are often used differently or even synonymously (Sperling, 2018). There are frameworks are getting used to define levels of automation. This report uses the 5-level system by the Society of Automotive Engineers (SAE, J3016) which specifies Levels 1 and 2 as including automated features that are already available in the market, example - self-parking, lane changes and adaptive cruise control. Level 3 automation can fully drive itself, though the driver needs to be ready to take over on short notice by having their hands on the wheel and eyes on the road. A FAV is in the realm of Level 4 and 5, which requires no driver attention. A Level 4 AV can drive in most but not all possible conditions, e.g., extreme weather or a traffic emergency). A Level 5 fully automated vehicle (FAV) can drive itself in all possible conditions.

The fully automated vehicle (FAVs) is not available for sale at present and missed plans announced by automobile manufacturer. In recent, GM (General Motors) has announced plans for privately owned fully automated vehicles (FAVs) to be available by the mid-2020s. The freight operators and heavy-duty vehicle manufactures are working on automation technology for long-haul trucking (ICCT, 2018). The fully automated vehicles are nascent stage of prototyping and under validation in relevant conditions like road and with real traffic conditions.

The fully automated vehicle in future will impact significantly society include travel vehicle and housing choices, patterns and overall environmental impacts (Milakis et al., 2017). There is high level of uncertainty about fully automated vehicle (FAV) deployment like for passenger travel or freight, private or shared vehicles and of societal impacts. The optimization modelling studies have shown the dramatic potential for positive impacts resulting from best case conditions: a fleet of shared, automated, electric vehicles. As examples:

•The greenhouse gas reduction (GHG) cut can be done with combination of the solutions per kilometres (PKM) by 87-94% compared to conventional vehicles. Even though average speed vehicle travel and vehicle size increased (Greenblatt and Saxena, 2015).

• The study done in Portugal (Libon) demonstrated benefits of fleet services are as below.

- fewer vehicles by 97 %
- parking place 95% less
- vehicle kilometres reduce 37% and less operating cost (Viegas et al., 2016)

• As per study in New York, 98% taxi demand could be achieved by 15-20 % of the of the vehicle provided shared or automated vehicle available with no adverse impact on the service.

However, there is a much wider range of potential energy and GHG impacts, which includes large potential for negative impacts. The boundary condition detail of fully automated vehicles are useful to do understand estimated energy to be use, greenhouse gas emission impact, consumer acceptance and technology application (Wadud et al., 2016). As examples of positive impacts, the authors find that FAV deployment could reduce energy use if it leads to more eco-driving and platooning and switching to smaller, less powerful cars, especially if deployed as part of shared mobility programs. There are potential identified negative impacts of fully automated vehicle.

The fully automated vehicles (FAVs) could use high energy due to increase of speed on highway, the user like elder people and people with disability will start high use of vehicle due to easier and cheaper way of travel (Wadud et al., 2016). The once of adverse impact scenario of fully automated is increase private vehicle ownership over other modes call for increased use of private vehicle. The user will use automated vehicle for move more drives if per VKM cheaper and the travel time utilisation for other activities like work. For example, FAVs could lower the costs of ride-hailing by removing the need for a driver. The fully automated vehicle will increase due to deadheading VKM when do human driver and need to part vehicle at home for free days when owner at workplace. The opportunity to covert empty ride by ride hailing for next customer.

This will help to reduce driving and operation costs of vehicle and freight trucks with increase travel of vehicle. The Sweden simulation study fully automated vehicle will increase overall goods-movement or VKM by 22% for passenger vehicle and trucking VKM increase by 35% (Engholm et al., 2021).

FAV technology brings many potential opportunities. To move towards the GHG-reducing scenarios, climate policy will likely have to play a strong role, especially road and carbon pricing. The one the point to reduce the greenhouse gas emission is to toll vehicle with zero occupancy (Bahrami and Roorda, 2022). As noted, the optimal scenarios tend to occur when automation is combined with shared and electric mobility. A recent study finds that shared, electric FAVs could reduce GHG emissions by 20% compared to private owned electric FAVs—with 33% reductions if pooling is used. There also is a need for increased attention to urban planning, especially to avoid the potential for FAVs to increase demand for low-density, suburban living that leads to longer commute distances.

#### 2.14.9 Climate Policy Options, incentives, regulation

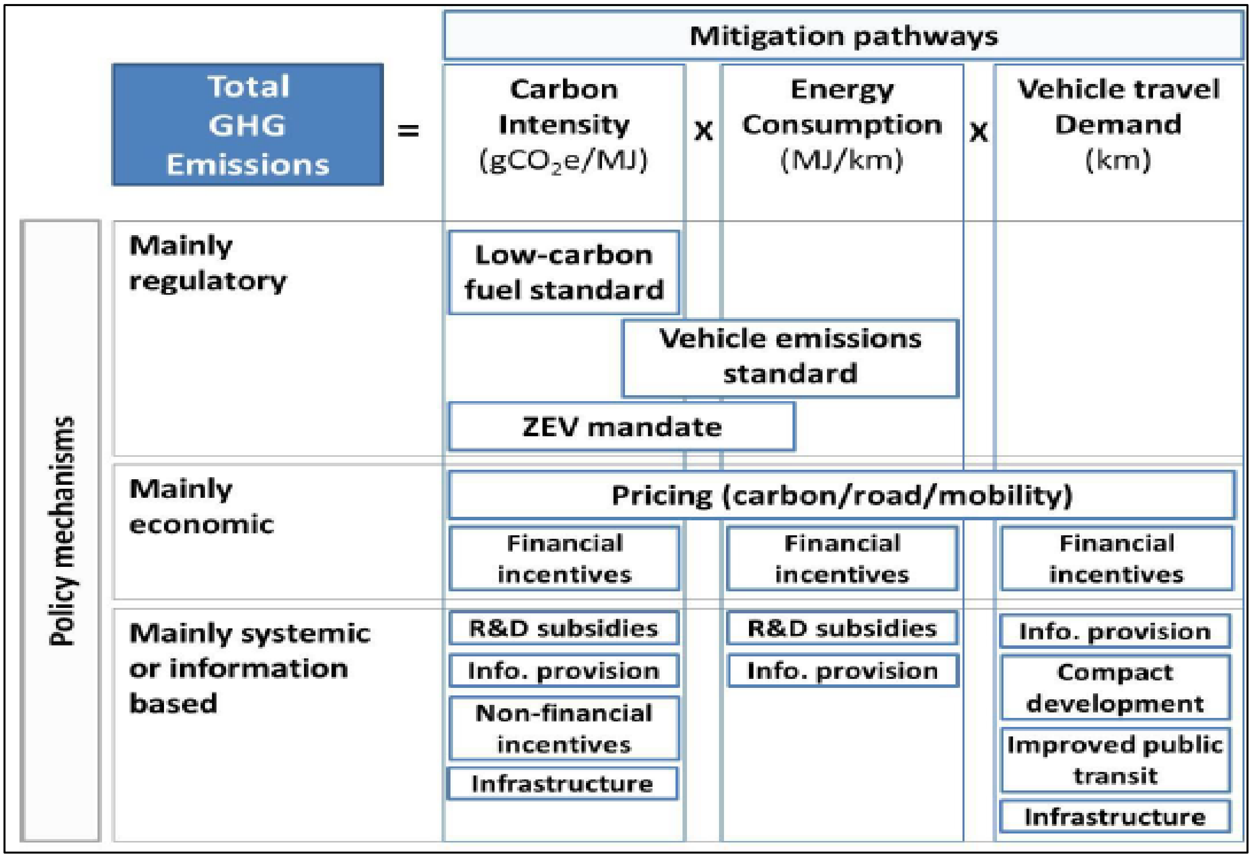
The effective implementation of deep decorbanisation technologies required the policies support. These deep decorbanisation technologies should be emphasized on the

1. low carbon of the technologies
2. technology innovation
3. development and usage.

The current policies are focused on the 3 mitigation ways.

i. switching to lower carbon fuels
ii. improved energy efficiency
iii. reduced vehicle travel demand.

**Figure 2.12 road transport policies and mitigation pathways**




As per data strong an integrative mix policy is needed for a low-carbon transition. The policies integration mix requires required a combination of below (Figure 2.12).

i. of pricing mechanisms

ii. subsidies

iii. regulations and

iv. infrastructure implementation.

There are detail studies done on effective policy mixes (Axsen et al., 2020; Creutzig et al., 2011; Kivimaa and Kern, 2016; Eggert and Sperling, 2014). The comprehensive policy mix has considered below points.

i. policy impacts

ii. interactions according to numerous evaluation criteria

iii. GHG emission reductions

iv. impacts to other societal co-benefits (air pollution, health, etc.)

v. cost-effectiveness or efficiency

vi. political or social acceptability and

vii. transformative signal (Axsen et al., 2020).

Most of the climate policy and research has focused on countries in Europe and North America and China. The many findings of this can potentially transfer over to developing countries. As per current policies study further research needed to focus on unique contexts.

**Pricing mechanisms**

As per many economies the pricing mechanism is considered the ideal due to potential effectiveness and efficiency. The carbon price allows firm or consumer to select option with lowest cost mitigation. The possible options are as below.

1. low-carbon fuels
2. efficiency
3. reduced travel
4. simply to pay the tax and continue with the status quo (Azar and Sanden, 2011).

The emphasizing on the pricing can play a strong role in deep decorbanisation (GHG) target. As per detail to achieve the Paris agreement goals required carbon pricing and high-level commission on indicated below carbon pricing range.

1. US$40-80 per tonne of CO2 by 2020
2. US$50-100 per tonne of CO2 by 2030 (High-Level Commission on Carbon Prices, 2017).

The pricing mechanism modelling noted mitigation strategy mentioned over and above 2040 and 2050 plan (Bataille et al., 2018; Guivarch and Rogelj, 2017). At present the pricing mechanisms is currently exist in regions which account for only 20% of global greenhouse gas (GHG) emissions. The lower than 5% of these priced emissions are at levels consistent with Paris Agreement goals (World Bank Group, 2019). The road or mobility can include carbon pricing and fuel taxes. But more often refers to cordon pricing and it include below.

i. congestion-based pricing

ii. distance-based pricing and

iii. parking prices

But the road pricing policies are often focused on congestion reduction. This include raising funds for transportation management and can cut CO2 emissions by 2-13% (Cavallaro et al., 2018) even cut vehicle travel by 4-22% subjected implementation over decades (Rodier, 2009).

The travel or fuel consumption mechanism will help for CO2 mitigation across the different design types and road pricing schemes rather than congestion reduction goals (Cavallaro, Giaretta, Nocera, 2018; Rodier, 2009). The long-term pricing mechanism can mitigate the anticipated rebound effects. Which is due to travel offered by future mobility innovations like electrification, ride-hailing (Boutueil et al., 2019) and automation (MacKenzie, Leiby and Wadud Z 2016). The policies study suggested that ZEVs tend to be heavier than conventional ICE vehicles. So, future road or vehicle taxes has to be partially based on vehicle weight (Galvin, 2022; Auffhammer, Shaffer and Samaras, 2021). But the major challenge of this is public acceptability due to evokes more public debate and opposition for this climate policies than other policies (Ardic et al., 2018; Dreyer et al., 2015; Combet et al., 2018; Rhodes et al., 2017).

**Market-oriented regulations**

The market-oriented regulations, which provide enforced and clear requirements for fuels or vehicles. These market-oriented regulations are included market mechanisms such as cost-effective policies to improve competition within low-carbon technologies for cost-effectiveness and credit-trading. Some policies are showing effectiveness in greenhouse gas emission reduction (Axsen et al., 2020):

i. Low-carbon fuel standard (LCFS): This is focused carbon content of the fuels used for power transportation (gCO2e/MJ).

   This implementation of this is happened in 2007 at California and now in Canada and Europe. The policy has assigns (WTW) well-to-wheel emissions for each fuel type (including electricity, biodiesel, ethanol and hydrogen) made from different source or feedstocks. This compliance credits are tradeable among fuel suppliers (including electric utilities) (Lade et al., 2016).

ii. ZEV sales mandate: As per this this policy automakers need to sales certain % vehicle (or market share) of ZEVs. This was 1st implemented by the California for light-duty vehicles and now in place in other several US states, China and two Canadian provinces. These policies are now being updated to ban ICE ban or 100% ZEV by 2035 or earlier. The zero-emission vehicle (ZEV) mandates have help to channelling technology development, boost innovations and increase sale of the net zero emission vehicle (Axsen J et al., 2021; Slowik and Lutsey, 2018; Nemet and Sierzchula, 2015; Farla et al., 2015). This is playing important role to mitigate greenhouse gas reduction targets (Sykes and Axsen, 2017).

iii. Vehicle emissions standard (VES): As per this this policy sets a minimum fuel consumption performance and/or tail-pipe CO2 emissions for new vehicles sell (gCO2e/km). This is included development of various technologies to improve efficiency (Lipman, 2018).

The Canada and US has received more support for above market-oriented regulations than any pricing mechanism (Axsen, Long and Kitt, 2020). The several studies suggest combining strong versions of these policies will be leading way to achieve deep decarbonization goals for passenger and freight sectors (Axsen et al., 2017; Axsen, Hammond and Kjeang E, 2020; Axsen and Lepitzki, 2018; Axsen and Sykes, 2017).

**Incentives**

This is included financial and non-financial forms. This include incentivize on ZEV sales through exemptions from vehicle purchase taxes or purchase subsidies. The exemptions for electrical vehicles are (road toll and high-occupancy vehicle lanes access or bus lanes) (Axsen, Moawad and Melton, 2017). In generally such incentives tend to have high public acceptability (Axsen, Melton and Moawad, 2020; Axsen, Jaccard and Rhodes, 2017). These incentives available to boost the electrical vehicle sales to need to be extend for a long duration (for decade or longer) to sustained greenhouse gas emission impacts (Chandan et al., 2017; Gnann et al., 2019; Axsen and Wolinetz, 2018). The purchase incentives are generally found to be a less cost-effective policy, with the potential for inequitable outcomes. The incentives for ZEVs purchase to be improve through various actions like design principles, caps on retail prices for eligible and subsidy caps on beneficiary household incomes. The incentives beyond financial supports like high-occupancy vehicle lanes access to ZEVs (irrespective of regardless of vehicle occupancy). These incentives have very less impact on long-term ZEV adoption (Hardman, 2019; Axsen, Melton and Moawad, 2020).

### 2.14.10 Deployment of charging and fueling infrastructure

The charging and refuelling infrastructure can support the adoption of ZEV. The initiatives like,

i. government sponsored charger and fuelling stations

ii. building standards that require charging infrastructure,

iii. financial incentives for infrastructure installation.

In passenger vehicle improvements to home charging has a higher impact than increased public or work-based charging (Chandan et al., 2018; Axsen et al., 2020, 2019, 2017, 2016). The increased public charging is an important to support car-buyers that live in attached homes and apartments (IEA, 2021). The charging infrastructure faces more challenging barriers for heavy-duty vehicles, and this require more advanced technology like Mega-chargers or catenary systems. Increased hydrogen fuelling infrastructure is particularly necessary for FCEV deployment (light- and heavy-duty), though it is not necessarily a sufficient condition for widespread sales (Axsen et al., 2020).

### 2.14.11 Research and development subsidies

Finally, subsidies for research and development (RandD) can support technology advancements in any of the deep decarbonization technologies noted above, including improvements in advanced batteries (cost and performance), fuel-cell technology, mega-chargers, catenaries, advanced biofuels, forms of shared mobility and automation technology. The past study suggests that RandD support for alternative fuels required strong funding and should not move is not move repeatedly in few years from one low carbon fuel to another. (Axsen, Melton, and Sperling D, 2018). The sustained support is required to overcome transformative barriers faced by new deep decarbonization technologies (Rohracher and Weber, 2012). The policies should send short- and long-term transformative signal to private industry to channelise innovation activity for ZEVs and low-carbon technology.

This signal can work with below.

i. policy or policy mix is stringent and long-term

ii. clear enforcement and penalties for non-compliance and

iii. trust that the policy will stay in place over time (Axsen et al., 2022; Nemet and Sierzchula, 2015).

### 2.14.12 Summary of decarbonization

The light duty vehicle deep carbonisation is readiness is highest. The bus and truck have strong potential for GHG emissions reduction. The light-duty and heavy-duty applications are expensive with very limited refuelling infrastructure and, many barriers to assure green hydrogen. The readiness for advanced biofuels is also low. They are the potential to increase the advantage given that they can be used in blends with existing gasoline or diesel-based engines, but the development and market penetration of low-carbon ethanol and biodiesel has been limited in the last decade. In terms of shifting travellers away from private vehicle ownership, several forms of shared mobility have made dramatic market progress in the last year, namely ride-hailing, car-sharing and micro-mobility.

The new mobility concept has not found the clear evidence of net carbon benefits even no privately owned vehicle in this category. However, these modes have not substantially displaced privately owned vehicles, nor is there clear evidence of a net carbon benefit. Finally, vehicle automation is in a relatively early stage of development and the potential future impacts are enormously uncertain. Such technology would likely need to be carefully paired with low-carbon fuels and/or shared mobility, as well as strong climate policy, to achieve the more optimistic automation scenarios.

The preliminary focused of the policies analysis is on the technologies as well as market progress and potential for greenhouse gas reduction (GHG). It is beyond the scope of this first report to provide specific recommendations. However, it is clear that the observed technology readiness and GHG potential is highest for PEVs, with more challenges and limited potential for FCEVs and advanced biofuels. The shared mobility has demonstrated market readiness but limited greenhouse gas reduction (GHG) potential. The noted climate policies can help to support further development of each technology and to assure that RandD and innovation activity is directed towards low-carbon versions of each.

**2.14.13 Next steps of decarbonization**

The decorbanisation studies of various technologies, country wise detail, regulations and policies has decided several steps. The more comprehensive analysis of the social, institutional, economic and business barriers and opportunities for each technology to be line-up for sustainability. The developing countries uncovered details, barriers and opportunities to be discussed moving forward (the countries are in Africa, Southeast Asia and Central and South America). The more thrust is required on the climate policies categories and ability to overcome identified barriers. The next decorbanisation technologies and list of categories are as below.

- The focused on Smart charging technologies, example - vehicle-to-grid (V2G), vehicle-to-home (V2H)

- The sustainable battery chemistries development (notably lithium-ion and solid-state batteries)
- The battery issues, such as materials, recycling and second-life or second use of batteries.
- The electrified road (example - overhead catenary lines for heavy-duty vehicles)
- The advanced chargers (example - mega-chargers for heavy-duty PEVs)

**2.15 Sustainable Mobility: Interdisciplinary Approaches**

There is continuous growth in GHG (greenhouse gas emissions) from the transport sector. This has led to start decarbonisation and a sustainability transition discussion in all sectors. At present this is largely driven by technology and supply-side such as vehicle and infrastructure. The vehicle engine technologies, clean fuels, smart mobilities and autonomous driving vehicles are dominant topics and covered in megatrend. Along with this the transport research and policy are also trending discussion. The important issues such as,

i. why people move in daily life the way they do,
ii. how mobility is linked to societal norms, expectations and aspirations for the future,
iii. what it implies for the natural environment remain under-explored, despite their close links to transport-related unsustainability.

These knowledge gaps on above issue can be partly attributed to the resistance of social and scientific perspectives. There is individualistic approaches dominance in transport research in past and at present. As per sustainable studies in field of the transport interdisciplinary approach is most suitable. The traditional mobility sector is base from which unifying core can be drawn. The traditional mobility sector doing certain resistance for change that is typical for more established and institutionalized disciplines. The concept of sustainable mobility is taking shape to define by the ways people moving, environmentally responsible and economically viable, has also gained traction in research, policy and public life.

The complexity of sustainability and sustainable mobility has taken attention toward current narrow and limited approach of disciplinary inquiries. As out of this greater attention moving toward interdisciplinarity and the adjustment of common impact factor to capture the benefits of inter- and transdisciplinary sector. The funding opportunities are an essential ingredient of successful interdisciplinary collaboration in research. The transport and mobility studies have studies that past mobility research are confined to single discipline. But there is discernible shift toward interdisciplinary sectors and this is special issue getting captured in major research.

The recent research in this discipline links travel demand, transport planning to other fields such as public health (Gerike et al., 2019), gender (Hanson, 2010; Christensen, Levin and Uteng, 2019.), environmental and transport fairness (Vanoutrive and Cooper, 2019) and (Verlinghieri and Schwanen, 2020), spatiotemporal accessibility and the debates associated with it (Morris, 2019; Levine J, 2020) and sustainable consumption.

The interdisciplinary research scope and nature for future mobility is still debatable regarding level of integration of across boundaries and methodologies used in research. The one of the studies conducted with 5 years collaboration of mathematician, transport engineers and social scientist and purpose of this study to investigate travellers' behaviours. The intent to this data collection is to initiate paradigmatic shift (Hulsmann et al., 2013). This research has noted very the interesting merits and demerit of interdisciplinary transport research.

The past research under title of the "sustainable mobility - interdisciplinary approaches" has captured trends in interdisciplinary mobility research, focused on methodological innovation, advancement done by bringing together researchers from different disciplines and research on critical perspectives on disciplinary divisions in mobility research.

The research in this area has studied the possibility of creating car-free cities, neighbourhoods through deliberate planning, targeted policy initiatives that extend beyond existing disciplinary, administrative boundaries to analyse the impact of parking restrictions and other parallel provisions (Envall, Henriksson and Johansson, 2019). The complex exercises are done in interdisciplinary area to capture individual behaviour and interdependent coordination processes between networks of people and things. The interdisciplinary studies have understood that mobility as the outcome of complex chains of decisions, people's social reflection, cultural, material circumstances, research and policy beyond disciplinary boundaries and conventional understandings of mobility.

The interdisciplinary studies also reflect on the role of conceptual and methodological tools to accelerate successful interdisciplinary collaboration and exchange ideas in the field of mobility research (Flipo et al., 2018; Fanderl et al., 2019; Durán et.al., 2020). These studies have provided rich evidence of the advantages and limitations of an interdisciplinary approaches which focused on coworking and its links with mobility and sustainability (Flipo et al., 2018). The initial exchange between different disciplinary background is needed to make visible contribution among partners and creatively utilise co-existence of diverse (potentially divergent) important concept as a mobility and sustainability. In interdisciplinary mobility research, the demonstration of the necessity of debating methodological preference (Flipo et al., 2018) and choices are discussed in open manner (Flipo et al., 2018; Fanderl et al., 2019) and critically examine a concrete example of interdisciplinary integration.

The past research has demonstrated that a shared conceptual framework has revolves around the notion of a 'boundary object'. This collective group analysis and exchange of mutual learning promotion across disciplinary boundaries. The linkage between the mobility and energy in urban area has investigated. The research work in interdisciplinary for mobility has work encourages to engaged in/about to look beyond consensus. Even this has help to for emerging divergences in traditional conceptual views, methodological orientation to generate fresh insights and advance scientific knowledge. The past research of interdisciplinary approach has recommended future interdisciplinary work at the intersection between research and policy in mobility.

### 2.16 An Inter- and Transdisciplinary Approach for Sustainable Mobility System

The future mobility, sustainability research looking for concrete solutions at present. There are research's done with inter and intradisciplinary approach for" future mobility". In this research below points are involved.

1. The involvement process for stakeholders in research and development and become co-designers
2. Suitable process to ways of supporting and facilitating interdisciplinary exchange
3. The joint work requirement at different place of interdisciplinary sector

These studies carried out are at technical in nature and important consideration at time of the studies toward "sustainable future mobility". As per studies fundamental changes in behavioural science is essential for sustainable future mobility and mitigating climate change (König, Gebhardt and Brost, 2019). So, the points beyond technical like user acceptance, user willingness and ability to change long establish behavioural patterns are important considerations.

The limited research in has evaluated the factors such as usability, economic issues and dependency on different field for sustainable future mobility. The past research conducted in future mobility are highly intradisciplinary and limited focus on the interdisciplinary nature. The interdisciplinary nature is required the involvement of various discipline experts in research process. The sustainable is not individual field subject. So, sustainable future mobility research are required knowledge and deep studies related to social, political, regulation, behaviour, attitudes and values, perceptions, economic incentives value-added chains, daily routines of user and consumption patterns (Grunwald and Padmanabhan, 2018).

The interdisciplinarity approach is important for future mobility product and service development. But this are needed to co-create along with those who use this. The prospective user's behaviour and decision process mechanism study are important elements to understand more in depth about the human behaviour for Future mobility. The past research has understood the need to observe below point in interdisciplinary studies.

i. what people do and
ii. what happens to them when they are not confined to limited environment
iii. what are involved in their normal lives in real ecological settings

### 2.17 Transdisciplinary Development of a New Sustainable Mobility System

The research demonstrated that the government and funding agencies observed and reach to consensus that sustainability and inter – transdisciplinary are interconnected to each other. The future mobility development is sustainable by making people participation as central to development process. For sustainable mobility has required reduction in noise pollution and greenhouse gas emissions, enhances the quality of life and accessibility to all user groups, optimizes efficiency and cost effectiveness among others (Richardson, 2005). The is definition from the "Brundtland Commission's" to define planet-wide sustainability as "the ability to meet today's transportation needs without compromising the ability of future generations to meet their transportation needs". The sustainability is complex, ambiguous and multi-dimensional. So, there is no simple single solution is not existed (Schneidewind and Augenstein, 2012). So, transdisciplinary development process could contribute to achieve the aims of creating sustainable outcomes (WCED 1987). The sustainable future mobility development has three dimensions: environmental, economic and social (Suchanek, 2019).

### 2.18 Mobility-On-Demand-Systems as Sustainable Transport Services

The on-demand mobility service spreading has marked a transformation in urban mobility (Luederitz et al., 2017). It has provided the emergence to the new mobility providers. The on-demand mobility service has created prospective of new business segments based on traveller's demand for higher flexibility, progress in digitalization and the provision of real-time information (Liyanage, et.al). The mobility on demand concept meets the requirements of a society that strives for personalization and flexibility. These has operated in a demand-oriented way that adapts the route and schedule as per the actual demands of users (Bakker, Savelberg and Moorman, 2017). The on-demand mobility service data base is increasing and analysis of same indicates that mobility-on-demand services can provide numerous benefits such as transportation efficacy, users' satisfaction and the environment.

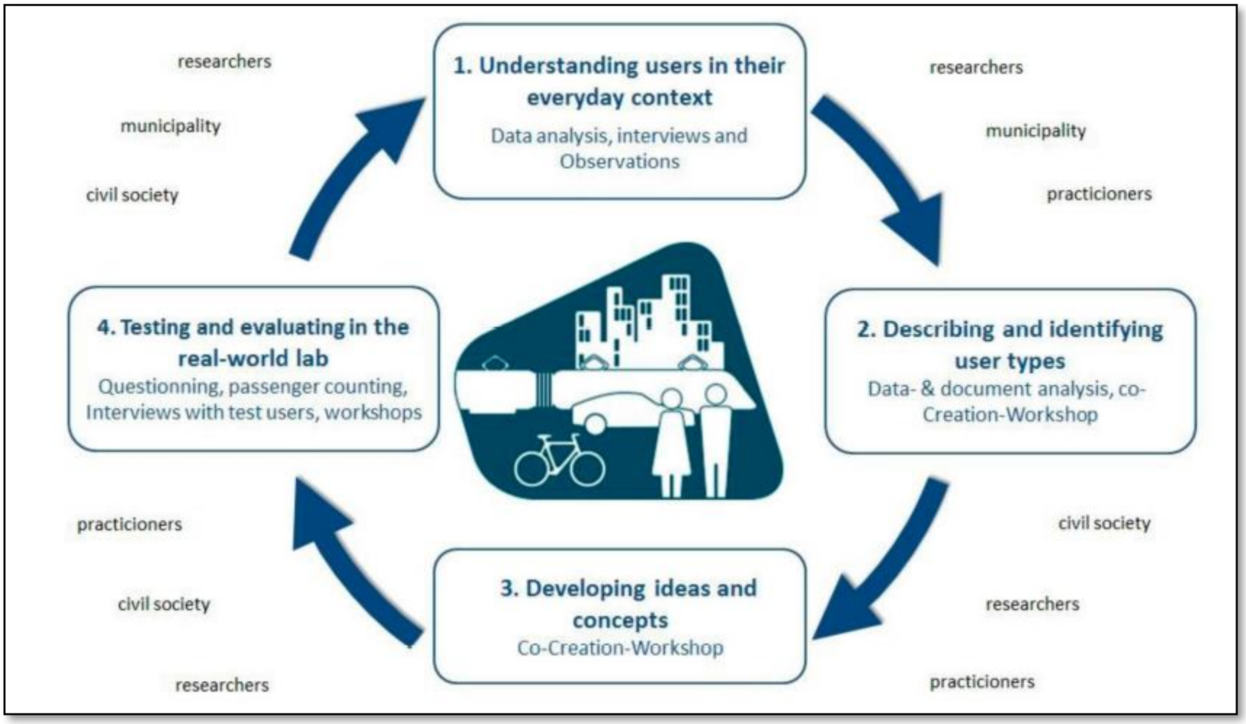
The on-demand mobility service can be served as a feeder to transit lines for public transport and contribute to resolving the challenge of the first and last mile by providing seamless and comfortable travel connections to facilitate intermodal trips (Beiker et al., 2016). The on-demand mobility service are matching users' ride requests through ride-sharing schemes. This are considered as one of the sustainable mobility options. Since as per assumption these are reducing the emission by pooling rides and increase occupancy rate of vehicles. As per review technological, social, ecological and economics factors are impacting on the on-demand mobility service. So, to make on demand mobility service sustainable to the market, travellers' preferences, needs, user acceptance and willingness to be considered early in the development of mobility (Jokinen and Sihvola, 2019).

The research understood that mobility is a socio-technical phenomenon (Fraedrich, 2014). So, to develop an appropriate mobility service for public, the public participation as co-designers requires. This co-designer concept will create transdisciplinary approach and give lead for further application development. The research has conducted on this concept. In this research instead of the 1st data generation about user behaviour and preference, transdisciplinary approach has developed with members of public to provide a sustainable solution for public transport. In these studies, the steps follows are as a below.

i. analysing the behaviour of potential users
ii. over to the identification of user groups and possible use of the new system
iii. to the generating of ideas and concepts and
iv. lastly testing and evaluating the new system

The research conducted is titled as "Transdisciplinary Development of Socio-technical Systems". The real-world laboratory Schorndorf has demonstrated the application of the transdisciplinary approach. The goal of this was to develop a procedure which can be used in other contexts to develop socio-technical systems (Gebhardt et al., 2018).

**Figure 2.13 User centric procedure and participant's phase**




The benefit of this approach is table as bellow in four categories (Figure 2.13).

i. The social dynamics and transformational processes – observation and understanding
ii. Synergy establishment - by integration of different disciplinaries sector
iii. Public acceptance - enhancement of new services and products
iv. Innovative potential of public- activation and empowerment of members of the

This type of research has been done in past by bringing different discipline scientific scholar of science background. In that trans-disciplinary approach benefits have been seen. The once of the important finding noted in this study that along with scientific scholar the knowledge of residents is equally as important and valuable. The sense of ownership and personal consternation is essential prerequisite for sustainability. This can be brought by involvement and interventions of local people (Kumar, 2002). The right time for involvement is early involvement of the public to increases the acceptance of a newly developed product or service. Along with increasing acceptance, innovative potential of a society can be encouraged at right time by applying transdisciplinary approach. The development of product is successful or not, but this approach allows to think ahead of social negotiation processes and to elaborate on model solutions. The process followed in this approach will allows to experience and understand social dynamics in complex socio-technical systems. These research findings should encourage urban and transport planning to pay more attention to the benefit of early and continuous participation of the population (Reurbanisierung and Urbanczyk, 2012).

### 2.18.1 Challenges of the Transdisciplinary approach

The challenges and drawbacks have considered when applying transdisciplinary research methods to the field of sustainable transport. These challenges can be clustered into four levels:

i. The cognitive - epistemic level,
ii. the social and organizational level
iii. the communication level and
iv. the factual-technical level.

In past research identified key challenges for the transdisciplinary projects.

In transdisciplinary knowledge of general public to recognise and appreciate the was challenging throughout the project. In this a common understanding of the real-world laboratory approach has helped for securing a common identity of different actors of transdisciplinary (Alcantara et al., 2018). In this process at a social and organizational level, the social bias in the process of selection has considered. In scientific discussion this concern has negotiated under the term “crisis of representation” (Grosvenor, 2000; Michelsen and Walter, 2013).

It is observed that the participation depends to a great extent on individual resources, participants usually come from a similar socio-economic milieu (middle-class, male, without migration background, aged above average). In contrast, migrants, young people and members of lower income classes are underrepresented (Blühdorn, 2013; Arlanch, 2011). The participants, at the social and organizational have the prioritization of diverging interests. In research the interesting observations and learnings noted are as below.

i. for a city a main goal is flawlessly functioning system
ii. for a researcher - the processes of failure, of negotiation, or even the non-acceptance of the citizens towards innovation and learning processes

At the communicative level, several challenges and drawbacks at transdisciplinary projects.

i. 1st challenge is, the common language within the team, it includes the same understanding of the terminology and methods. This required a mutual learning which studied in the reflection of other real-world laboratories (Bergmann et al., 2017).
ii. The participant from different discipline has different perspectives within the team of researchers. This has become evident at time of deciding on concepts, working methods and methodologies.
iii. For participatory process the efforts (and costs) of communication, organization and evaluation are high. So, this should be considered in the planning phase of a project (Alcantara et al., 2018).
iv. This approach faces the challenge of translating 'soft' and qualitative findings into 'hard' technical system requirements with accurate technical terms.
v. In one hand, at design and development level the system meets all relevant stakeholder requirements. Bu in other hand represents a functional, sustainable and efficient system has challenge. So, in this case right trade-offs with carefully and transparent communication to all concerned person is important.

### 2.18.2 Important findings of the Transdisciplinary approach

The trans disciplinary approach has studied to develop the mobility-on-demand system. The important recommendation has been noted. In many of the recommendation are matching with former studies recommendation. The important recommendations are as below.

i. Acceptance and appreciation of the character of an explorative experiment. This is indicated that, open to any development and results being flexible. So, setting up the real-world laboratory is not only important but experiments to be done on existing and specific characteristics (Bulkeley et.al., 2011).
ii. The citizens and local stakeholders to be involve at as early as possible and define the research question from the beginning (Martin, 2008)
iii. The new mobility concepts have to provide sustainable solutions by integrating different users' groups and local partitioners along with selected user groups.
iv. Involve the various groups of citizens in the participation process to reflect the heterogeneity of society (Kolleck, 2016).
v. Empower the people through authority and implement the innovations by involving municipality and decision makers (Alcantara et al., 2018; Taylor, 2007).
vi. Create the shared platform or tool to generate knowledge and facilitate the joint work by documenting. This is to unify knowledge level of the team.
vii. The new thing to be try with courage. There is learning form great failure deals and such transformational processes can be used for future negotiation, generate knowledge and experiences in a real-world context and use the pilot phase to test and experiment (Beecroft, 2018; De Flander K et al., 2014; Bulkeley H et al., 2011)
viii. Increased awareness and value confrontation of a topic as a success. Even there is no change in behaviour seen or measured, the process of awareness raising in citizens regarding sustainability question itself can be bring a success. The transdisciplinary approaches have an inherent responsibility raising social awareness (Jolanta et al., 2012).

ix. Do not be concerned by resistance to change. The mobility is deeply shaped by routines, people do not change their behaviours overnight. The transformative processes need time and within these processes, you can learn much about the fears, requirements and learning abilities of people. An iterative development process integrates new insights in the development of the service and try to consider the concerns of users by using same. The long pilot phase to facilitate more thorough assessments of the transformative processes. So, this can be tried where possible (Alcantara et al., 2018).

The above-mentioned practical recommendation can be implemented by considering regional boundary conditions at time of experiment. As per assessment, the routines are not changed overnight and it takes time to recognize, initiate and map long-term transformative processes. The long-term studies could measure these processes of change. The past and current research projects and funding instruments are designed for a limited period of time. So, this is offer little room for transformation. So as per past research important to discuss the new formats and forms of transdisciplinary research and to create appropriate framework.

### 2.18.3 Past interdisciplinary sector integration recommendations

The interdisciplinary sectors research has noted the budget realities and contexts of individual communities may concentrate on some suggested impractical or premature, or unnecessary strategies. However, communities who have declared a climate emergency should prioritize as many strategies as possible to accomplish their emissions targets, as well as to improve the health and well-being of their residents (Table 2.1). The pandemic has provided an opportunity to spark changes to urban mobility patterns; however, appropriate supports are immediately needed to ensure this opportunity is not missed.

**Table 2.1 recommendation and effect of sustainable transportation**

<table>
<tr><th>Recommendation</th><th>Intended Transportation Effects</th><th>Health and Environmental Effects</th></tr>
<tr><td>Support the creation and development of accessible and safe active transportation infrastructure.</td><td>Increase in the number of residents who choose to participate in active transportation will lead to a reduction in personal vehicle use.</td><td rowspan="5">Direct health benefits to the users of active transportation.<br><br>Decrease in GHG associated with reduced number of vehicles.<br><br>Improved air quality associated with reduced particulate emissions.</td></tr>
<tr><td>Incentivize and prioritize use of active, public, and shared transportation over use of personal vehicles.</td><td>Increase in the number of residents who use active or public transportation will lead to a reduction in personal vehicle use.</td></tr>
<tr><td>Ensure connectivity of active transportation infrastructure with major destinations and public transportation options.</td><td>Connectivity is a significant barrier to active transportation and public transportation use. Thus, work should be prioritized to facilitate greater uptake of both modes of transportation. This will lead to a reduction in personal vehicle use.</td></tr>
<tr><td>Work towards low-carbon, personal and public transportation, e.g., electrification and hydrogen.</td><td>A higher proportion of low-carbon vehicles will lead to a reduction in greenhouse gas emissions from personal vehicles and public transportation.</td></tr>
<tr><td>Work across siloes to improve integrated mobility to impact climate and health related outcomes.</td><td>Equitable, barrier free, eco-friendly mobility.</td></tr>
</table>

### 2.18.4 Transportation Infrastructure - Suggested Strategies

i. Prioritize people over cars by policy creation and practicing. The some of these can be taken as a revenue generating (Fraedrich and Lenz, 2014).

ii. At time of the new road development, inclusion of appropriate sidewalk, bikes lanes, or multiuse pathway to be consider as check points (Klein, 1990).

iii. The obstruct such as delivery vehicles, service vehicles, construction sites or personal use vehicles should not be allowed. The policy to be discuss for no obstruction to sidewalk and bike lane and heavy penalties should be introduced for such offenders (Evans and Karvonen, 2014).

iv. The snow clearance and maintenance priority to be given to bike lanes, sidewalks and multi-use pathways in snow area (Bergmann et al., 2015).

v. The high-quality infrastructure to be created to encourages active and public transportation.

v.a. The painted lines should not be used for bike lanes as they are not safe. Even this should not encourage for active transportation (Cornet et.al., 2015].

v.b. The awareness to be create in the societies related to the active transportation infrastructure (Augenstein and Schneidewind 2012).

iii. The prioritisation of the active and public transportation at major destination and route such as railway train station, universities campuses, hospital etc. (Bakker, 2016).

The infrastructure to be maintained irrespective of initial usage (ITF, 2016).

The cycling to be encourage for local destination.

The bike parking infrastructure to be created to minimize theft (Jokinen et.al., 2019).

The diverse group of individuals from community to be include at time of planning.

i. The age friendly transportation to be create (Pohl C, 1999).

ii. The representation of the disabilities and advocates from disability group (Cleaver, 1999).

Incentivize and prioritize use of active, public and shared transportation over use of personal vehicles suggested strategies are as below.

i. The unfit vehicles to be remove form the roam to improve air quality and health (Bergmann et al., 2010).

ii. The financial incentives to be provide for purchasing and using e-bikes for short trips (Defila, Giulio and Olbertz, 1998).

iii. The encouraging incentives to be provide for leaving the car at house (Beecroft, 2018).

iv. The parking cost at municipal facilities to be increase (WBGU, 2011).

v. Make public transportation free of charge (Bergmann et. al, 2018).

vi. The discounts in parking fees for carpooled vehicle (Bradwell and Marr, 2008).

vii. Strat imposing per vehicle-kilometres travelled (VKT) tax which to be start from delivery of vehicles (Franz Y, Tausz and Thiel, 2008).

viii. The transportation sector should provide real-time emission monitoring data and communication of greenhouse gas emissions by community (Juujarvi and Pesso, 2013).

Ensure connectivity of active transportation infrastructure with major destinations and public transportation options suggested strategies to develop an integrated transportation system are as below.

i. The Integration of train and bus stations with active transportation for individual's travel. So, they will not have forced to use a personal transportation and vehicle to get to major public transportation hubs (first mile, last mile) (De Marez L and Schuurman, 2012).

ii. Connectivity improvement throughout community and through well-known routes – this includes connection of the overpasses and bridges for pedestrian and cyclist. So, they need not to wait at light crossing or cross busy intersection (Gebhardt et al., 2018).

iii. The bike lanes and sidewalks should not abrupt ends forcing commuter to come on road (Hennen. L 2012).

iv. The ride sharing companies operating in rural and urban area should provide accessibility option to residents (Bergold and Thomas 2012).

Work towards Electrification of Personal and Public Transportation - Suggested Strategies

i. The charging stations should be available throughout the community and capacity to deal with increasing demand (Kramer, 2008).

ii. The prioritisation and financial incentives for electric cars and bikes parking (Miebach B, 2006).

iii. The financial Subsidiaries for electric cars and bikes (Watson, 2012).

iv. The public transport vehicle electrification (Arlanch et.al. 2011).

Integrated mobility to improve health and emission elated outcomes across siloes to improve

i. The different government departments and different levels need to work together for system to develop a system.

For eco-friendly and interconnected transportation facilities, the across government different department should ensure services and infrastructure

the government agencies should prepare for smooth transitions between active and public transportation (Charmaz K, 2014) the carbon price to be put to reduce vehicle person use:

Road tolls (Brost, 2018)

i. High occupancy vehicle lanes (Dubielzig and Schaltegger, 2014)

ii. Parking fees (Parodi, 2013)

iii. In new developing communities the connectivity and integrated planning need to be taken as priority.  This will help to reduce person vehicle use (Brost et al., 2012).

iv. The multimodal transportation to be encourage.  This is critical for ensuring that people of all ages, collars, income levels and ability levels can move in their community (Bulkeley et al., 2011).

v. The financial benefit and saving increase for household will help for faster sustainable mobility adaption.

### 2.19 Literature review Summary

The greenhouse gas emission and in transport sector is one of the highlighted and pressing complex concern. The greenhouse gas emission due to transportation sector is one of the largest sources and impacting detrimentally on climate and health outcomes. The placement and structure of communities are dictated by transportation. The congestion and fractured mobility services are largest drags in the economy and critics of well-being. There human health is ins concerning topic and impact by greenhouse gas emission. The technology like multi-modal transportation, active transportation, public transportation and electrification etc. are providing opportunity to enhance health and improve life by reducing environmental impacts.

This technology will help to strengthened and stabilize economy. It is time to move towards an integrated future mobility approach. This approach needs drive in context of local and requires non-governmental leadership. Specifically, future research must design, implement and evaluate interventions that target an increase in use of active and public transportation in consultation with residents, advocates, professionals, municipalities and senior levels of government. So as per research along with government and other concerns non-governmental involvement approach is required.  There are gaps to ensure continuity of projects during changes in government and shifting government priorities

The literature reviewed has provided key insights on technology, innovation, strategies, economics, policy and consumer behavior toward future mobility. The insights studied are based on historical data, case studies, current conditions and plausible scenarios to understand future mobility. The challenges like climate change, local air pollution, traffic conditions, transportation, net-zero carbon emissions, alternate existing technologies and policy mechanisms has reviewed. Since limited practical data base research available on the future mobility.

The net zero 100 % emission are target for future mobility. But current available research state that by continues fuel efficiency improvement (increasingly fuel-efficient) ICEV vehicles is possible to achieve emission target. The individual countries geo-political and technological collaboration is required and at present limited data available on this. The alternative powertrain vehicle like BEV and FCEV are major focus in research of on future mobility and not as complete sustainability value chain.

As per comparative carbon emission intensity analysis conventional ICEV mobility fuel efficiency can be increased to meet emission target in short term. In long-term point of view various alternative technological innovations required to achieve global emission reduction targets. The net zero emission target mobility has been discussed but limited alignment of consumer to go ahead for BEV and hydrogen FCEV in sustainability point of view. This research gap is there because limited research available consider complete sustainable ecosystem.

There is conflicting consumer view regarding current and future mobility powertrain technology and no clear research answer to address this concern. So, to drive penetration of future mobility and address penetration issue detail substantiality research is required. The limited sustainable technological research and strategies are to address and due to this the conflicting future mobility technology acceptance. The integrated mobility sector research along with other energy sectors of the economy is required.

The multifaceted framing of mobility, perspective of sustainability, public health, urban development, personal identity, social justice and equity are available. The point such as congestion, accessibility, quality of life and urban life space has been studied as separately as sustainability. This research offers a stand-alone vision for each point and clear areas of divergence observed. The available research has not mentioned interlink and interaction effect of concern elements.

The major fucus for future mobility as sustainable in threat for climate change and pivotal point to attract consumer attention. The research in this front is very limited and not in-depth. But more research is in pipeline on his front. The current available research is not to addressing complete sustainability involve in alternate powertrain vehicle technology, social innovations, mobility service, renewable electricity grid, geo-politically collaboration and policy deployment.

The country and institution wise targets made for future mobility are linked with global climate perspective and sustainability agreement. The global and country wise policy are drafter and under review to make future mobility sustainable been drafted and global getting accepted. At present there is major gap in policies and industry looking to make mobility sustainable w.r.t. available technological and innovation.

The industry and societies are looking for further research on future policies to align for sustainability. In some of the research immediate political action has been asked to induct new policy and quick reframe ineffective current policies. As per there is gap in sustainable future mobility and concern ecosystem around it. This study has done to investigate requirement of future research on sustainability future mobility in aspects technology (alternate powertrain, mobility service, etc.) innovation and business strategies.

# CHAPTER III:

# METHODOLOGY

## 3.1 Overview of the Research Problem

At the global level, the decorbanisation of mobility is a major initiative to reduce greenhouse gas emissions. In India, the decorbanisation of mobility has started taking pace. The initiatives being discussed at global level and vehicles are net zero emission vehicles, decorbanisatin of mobility, alternate fuel and powertrain technology, mobility as service, micro mobility and so on. The major concept discussed at sustainable goal initiative for decorbanisation of the mobility is avoid, shift and improve. The megatrends like CASE and SAEV are also being discussed at the global and India level to decorbanise the future mobility. The megatrends are collective independent technology discussion for future mobility. In the past and current, the decorbanisation of mobility to reduce greenhouse house gas reduction is one of the sustainable mobility core element. In India, the projected mobility decorbinisation efforts are also majorly towards greenhouse gas emission reduction. Since, in past and at present, the mobility is around powertrain or motor centric vehicle.

From the last decade onward, mobility has been started shifting from powertrain or motor centric to other-forms of mobility, like micro-mobility, mobility as service and others. The evaluation of sustainable mobility has been happening for the last 4 decades. The sustainability of mobility depends on the interdisciplinary sectors or resources. The last one decade focus was on reducing greenhouse gas emissions and efficiency improvement by powertrain or motor technology. But the last 2 years study has acknowledged that the sustainable mobility concept is changing and contributing elements are changing. This research concluded that sustainability dimensions of mobility are changing. The various research studies, actual measurement, government laboratory and others publications on mobility has confirmed the green house gas emission levels due to mobility sector. The analysis of this data has concluded that mobility is one of the sectors that contributes to greenhouse gas emissions and needs to address this on priority.

The greenhouse gas emissions due to fossil fuel and electrical vehicle with different sectors of electricity are also tabled. The impact of mobility on social, economy and ecology has been discussed at vehicle levels.

The mobility has an important contribution to global and Indian economic growth. The importance of the mobility sector has been acknowledged globally and in India. The transport sector is a major consumer of materials (metal, polymers and other) and energy and contribution of each different as per individual mobility. The mobility is directly and indirectly responsible for greenhouse gas emissions and other pollution (soil and water). This is also responsible for road traffic crashes and road accidents. As per GDP ( gross domestic product) 2022 around 1.33 million people were killed in road accidents and this costing 3% of GDP for most countries.

In India and globally, social inclusion for mobility is very high. It is indicated that access to mobility and mobility services to the public is unequal. As per sustainable mobility studies, current mobility at India and global level is towards unsustainable. The mobility solutions implementation is long-term in nature and complex mobility systems make mobility patterns difficult to influence in past years. The long-term nature of this investment reflects in the transport sector and has influenced for a very long time. The long-term investments reflected in airports, roads and bridges have a very long life to achieve the investment return target. This will continue to influence. The investment in aeroplanes, cars and trains all have a longer life span and returns on fleet take decades. So, changing transport and mobility systems is a long-term process. The mobility and transport systems consist of 3 interconnected sub-systems.

Motorized transport – in this case, sustainable mobility requires an assessment of technological development and-total distance covered by each mode. So sustainable mobility is not limited to vehicles but concerns, about the level of mobility in society.

Transport infrastructure - sustainable mobility needs an assessment of all relevant impacts during construction (use, maintenance, etc), each mode of transport decommissioning (it includes the energy and resources embedded in the infrastructure such as concrete, asphalt and control systems).

The energy system – It includes the energy carriers that used to power the various modes of transport. Sustainable mobility requires a comparative analysis of the conventional energy systems with possible improvements and alternative energy systems. The alternate energy system requires the provision and use of transport and energy facilities (infrastructure). There are several other elements operating in and across mobility and sub-systems. These subsystems are along with governments (from local to at different levels), firms and the people.

In this research, we have studied the various strategies which has piloted and applied to achieve sustainable mobility. The strategies, such as avoiding the number of trips and length of trips, increase efficiency and facilitate shifts in mode of transportation. The various sustainable mobility initiatives are taken from combinations of these strategies. The sustainable mobility research is a set of actions to decide a way to proceed (applying initiatives and strategies) to achieve sustainable future mobility.

In the past, mobility research was confined to emissions and vehicle technology. But in future to achieve a sustainable future mobility the governments, various concerned firms people should be understandable, attracted and motivational to believe in the sustainability of future mobility. So, once they start believing in it subsequent support can be extended (Holden et al.,). The intensive research is required in 3 major subsystem and related systems to make future mobility sustaianble. It requires long term integrated assessment of the positive and negative impacts of each sub-system.

The research so far available is around motorised vehicles and technology related to same. The current mobility is not sustainable even with past research done in this area. So, to make future mobility sustainable, further compressive research is required. The ongoing research in the field of mobility is concentrating on megatrends, net zero emissions, decarbonisation, which are needed to address climate change due to greenhouse gas emissions. In this research there is focus on sustainability but not limited to greenhouse gas emissions.

The sustainable future of mobility is a vast area of research. As per the Indian context and global, the avaialble research in the area of mobility is to reduce greenhouse gas emissions. India has also committed to net zero mobility and decarbonisation activities inline with other countires. In this study, the Indian context has been taken into consideration and looking for sustainable future mobility. At present there is still very limited discussion and research on sustainable future mobility in the Indian and global context. As per research conducted in Indian context in sustainability majorly focuse is on the electric vehicle. The research has conducted in India context around an integrated approach for sustainable mobility.

### 3.2 Operationalization of Theoretical Constructs

The various research, initiatives and platforms are in India and global available for future mobility. This platform's major focus is on decorbanisation of mobility as a sustainable mobility solution. The decorbanisation major focusses on electric vehicles (BEV, PHEV, FCEV). There is very limited discussion and research toward sustainable future mobility beyond electrical vehicles. As per a press release in India, “future mobility has to be sustainable in the economy, ecology and environment”. The research, discussion and initiative are limited on this. The continuous efforts are ongoing in the area of future mobility and to reduce greenhouse gas emissions. As for sustainable future mobility, dedicated efforts are not found. As per data, India's motorised vehicle population is increasing and in the coming 5 years will surpass the European motorized vehicle market population. As per data, India is the fastest country for urbanisation and, with this, congestion keeps increasing.

India has participated in the decarbonization activities and decided on the net zero plan. The plan for the development of electrical vehicle is available and various initiatives around it. In 2020 India released the report “India Road map on low carbon and sustainable mobility (decarbonisation of Indian Transport sector)”. The various other initiatives are in proven like, Fuel mix – renewable source fuel

Hydrogen mission

FAME (faster adoption and manufacturing of an electric vehicle)

Policies around vehicles economic benefit

All these efforts are toward the decorbanisation of energy sources and reducing the greenhouse gas emissions for sustainable mobility. But there is a clear gap evident on scope, definition, requirement and action toward "Sustainable future mobility". As per a press release on the 30th Jan 2023 of the road and transport ministries, the future mobility to be sustainable for the ecology, the economy and the environment. At present there are very few studies available on "Sustainable future mobility" in the Indian context.

In 2020 India has released the report "The India Roadmap on Low Carbon and Sustainable Mobility". This report is a bottom-up stakeholder driven actionable vision and an operational focus on the transport sector in the context of SDG (Sustainable Development Goals) along with the objectives of India's NDC (Nationally Determined Contributions) under the Paris agreement. This report provides direction for policy visibility on low carbon and sustainable mobility ecosystem in India. In this report an integrated approach and actionable recommendations has been tabled. This report included short-term (up to 2022), medium-term (2022 to 2030) and long-term (2030 to 2050) plans for Indian mobility. As per the report, India has committed to climate goals and ambitious initiatives undertaken. In this context, inter-ministerial and extensive stakeholder consultation is leading a transformational pathway in the mobility sector. The transport and mobility sector are an important contributor to India's economic growth. So, the transition of mobility to a low carbon pathway is centralised to ensuring a move towards achieving the goal of a 5-trillion-dollar economy along with sustainable mobility in the country.

The roadmap of low carbon and sustainable mobility recognises air pollution and congestion at the core of the problem with decarbonising mobility. There is a recommendation and great thrust for public transportation, sustainable fuels, a shift in the paradigm of building infrastructure for mobility of vehicles. The strong recommendation for building infrastructure for mobility of people and goods and focusses on transit-oriented mobility development. The key recommendation is for the development of integrated governance at national, state and city levels.

The eight components have been mentioned in the report to provide a comprehensive and holistic outlook of solutions. This actionable agenda includes,

**i.** urban transformation

**ii.** low carbon energy supply

**iii.** inter-modal and intra-modal efficiencies

**iv.** reducing freight emissions

**v.** reducing vehicle kilometers

**vi.** making adaptation central to transport and urban planning,

**vii.** sustainable rural mobility,

**viii.** financial and economic instruments.

The report has been discussed regarding integrated approaches to policy, transport systems, infrastructure, mobility as service, integrated decision making, government policies. This integration is to go for decarbonization. In this sustainable future, mobility studies are not completely captured. Sustainable mobility is discussed in terms of decorbanisation. But "future mobilities are under development and various Megatrends define the future mobility. There are some indications that the next generation of mobility is coming out of the confined nature of motorising vehicles. So, there is a need for research on "Sustainable future mobility" and to study the way to make future mobility sustainable.

This research demonstrates that efforts are moving to make mobility sustainable but limited efforts to make sustainable future mobility. As per past research, sustainability in "future mobility is very important. This research focused on "sustainable future mobility" is required. The sustainable future of mobility is vast. Since this includes sustainability and future mobility as well. This is a very vast subject. So, in this research the Indian context has been considered.

The energy sector transition is a basic prerequisite to meeting future mobility requirements and meeting the climate protection goals of the Paris Agreement. This major consideration is greenhouse gas emission reduction. The new technologies for vehicles and infrastructure offer comprehensive solutions for the emission-free environment. The various data stated that 23 % of greenhouse gas emissions are attributable to the transport sector. The majority of this is due to motorised individual vehicle traffic and, as per forecast, mobility to increase by around 30 % by 2030. So, implementation of the climate protection plan in the transport sector is becoming important.

The various measures are to reduce greenhouse gas emissions such as car sharing, public transport etc. to meet a sustainable mobility objective. Digitalisation, automation, networking, AI (artificial intelligence) are at the centre of technology. The important focus is the development areas for future mobility are alternative drive systems such as alternate fuel, battery and fuel cells. The market share of the emerging mobility technology such as electric and hybrid vehicles is increasing. The challenges such as limited range, high acquisition costs, regional gaps in the charging infrastructure are under the technical innovation and scientific evaluation phase.

In the mobility sector, ecological, economic and social aspects are playing a more significant role in the mobility sector than any other sector. The basic prerequisite for a successful sustainable future mobility transition is social acceptance and the close cooperation between industry, science, technology and politics.

### 3.3 Research purpose and question

At present, future mobility is at a nascent stage in India. There is very limited research available to make future mobility sustainable. In the past 4 decades, mobility generation studies have stated that mobility sustainability is confirmed by the fuel economy and greenhouse gas reduction of motorised vehicles. But generation to generation scope mobility is changing and to address this future, mobility is evolving. As per the various future mobility studies, the scope of mobility is moving away from fossil-fuel motorised vehicles. So, the purpose of this research is to understand the need for "sustainable future mobility" and the scope included in this study. The long-term purpose of this research is to develop a framework for sustainable future mobility. In various reports, it mentioned that an integrated approach for sustainable future mobility is required. This will provide a comprehensive review of literature and industry practices and outline a conceptual framework for sustainable future mobility.

In particular, this study has the following purpose:

1. To provide a compressing review, decide to implement future mobility for sustainability.
2. To provide a framework for future mobility development
3. To identify the potential emerging business
4. To provide a foundation for future research to expedite sustainability aspects of implementation in future mobility

The long-term goal of the research is to enable the development of a sustainable future mobility. The sustainable mobility referred here requires integration at the intersection of vehicle, energy, infrastructure and consumer. As per past studies data, there is no single remedy to achieve sustainability. So, the purpose of this research is to identify and address the factors responsible for sustainable mobility. Sustainable future mobility requires integration or connecting mobility elements to each other in such a way that all parts have to be addressed whole. The result of this study will be valuable to society, consumers, mobility industry practitioners, other related industry practitioners, policy makers (government / public), as well as a related basis for future researchers to develop better solutions and tools for future mobility.

As per sustainability studies, an integrated or comprehensive approach is required to develop future sustainable mobility. The integrated or comprehensive approach is a very broad term. Mobility is cutting across all sectors. So, defining the integrated approach for sustainable mobility is required to understand concerns about each cross-sector point to develop sustainable mobility. The individual mobility solutions available are working very well. But as a system, they are not justifying sustainability. The noteworthy transformation detail is offering lessons to mobility industries.

The critical factors such as global competition, technological advances, autonomous vehicle (AV) innovation and investment in electric vehicles (EV) are playing critical roles. The numerous opportunities are showcased by well-established automakers, mobility start-ups by investor enthusiasm, strong auto sales, technological advances in vehicle connectivity, expanding sources of consumer data and potential new partnerships with tech companies. The critical transition trend such as global emissions, country-wise regulation, technological innovations, demanding consumer regulations, increased traffic congestion in urban areas, the speed of electrical vehicle adaption are defining the next level of challenge to future mobility for revolutionary change. This area is the beginning of a mobility sector shift with new opportunities and risks.

### 3.3.1 Research questions

To conduct the research below, a question has been framed. The answer to the question is expected on scale of the 1 to 10. In this 1 scale is strongly disagree, 5 neutral and 10 strongly agree. This question has been framed to get the current mobility status updated and input to "develop sustainable future mobility". The question are as below.

1. The ongoing and projected decarbonization initiatives will help to develop sustainable future mobility in India in the next 10 years.

2. The scope of future mobility is environmentally friendly, safer, accessible, affordable, reliable, efficient, and socially desirable.
3. The current and projected efforts in future mobility sectors are enough to develop "sustainable future mobility" in India. (Future mobility refers here – as an alternate fuel and power train technology vehicle, mobility as a service, connected car, autonomous vehicle, etc.)
4. The quality of life will improve with the implementation of "sustainable future mobility" in India.
5. The cost of living will increase due to the adoption of "sustainable future mobility" in India.
6. The lower total cost of ownership and increased affordability of mobility will help for faster "sustainable future mobility" in India.

7. Success of "Sustainable future mobility" in India requires contributions other than automobiles and transport. If yes, respond below. Please respond to sub-points from i to ix

7.i. Energy sector

7.ii. Human behavior

7.iii. Government policies and schemes

7.iv. Mobility as a service (Public transport, shared mobility, on demand service)

7. v. Commercial (Banking, Economics, finance and Insurance)

7.vi. New technology – digitalization, Artificial intelligence,

7.vii. Infrastructure and urbanization development

7.viii. Education sector (formal and non-formal education)

8.i. In an Indian context, "sustainable future mobility" needs, faster introduction and implementation of new technology like clean energy, battery electric vehicles, hydrogen vehicles.

8. ii. In an Indian context, "sustainable future mobility" needs, infrastructure development for electrical and hydrogen vehicles.

8. iii. In an Indian context, “sustainable future mobility” needs, current mobility efficiency improvement and parallel introduction of new technology in phase wise with a defined timeline target.

8.iv. In an Indian context, “sustainable future mobility” needs, human behavioral change towards mobility, adaptability and usage

8.v. In an Indian context, “sustainable future mobility” needs technological accessibility and affordability for mobility through economical solutions.

8. vi. In an Indian context, “sustainable future mobility” needs, customization of mobility within metro, urban, rural and to connect all these 3

8.vii. In an Indian context, “sustainable future mobility” needs focus on government policies.

8.viii. “Sustainable future mobility” can be implemented faster by comprehensive implementation of all the above section 8.i. to 8.vii. point together

9. Sustainable future mobility will help to boost social and economic development in India.

## 3.4. Research Design

### 3.4.1 Theoretical data collection

The past research in the field of mobility has been studied. In the literature review section, the part research gap has been studied and the appropriate gap taken for reference. This research gap has been studied to get direction to drive the research to the next level. This has been studied at global and Indian context level to get the right direction. In this section, past mobility research and concerned modelling has been referred to. For theoretical data collection, technical digital books, part concerned papers, publications, research thesis and concerned data has been referred

### 3.4.2 Data in India and global Context

As per the theoretical data collected in India and the global context. As per this detail, it is understood that the global data on future mobility is related to greenhouse gas emissions. The various global scenarios have been analyzed. There are very few details available about future mobility” as sustainability context. The efforts are mentioned to make future mobility sustainable. But this efforts inclination is toward emission reduction. The modelling data with various scenarios of emission reduction has been studied. The same level of data has been studied in the Indian context. The various future mobility initiatives have been studied. In the past, reductive mobility has been studied and emission reduction at the center of that study. The global and Indian future mobility data is in terms of various future mobility and growth projections

### 3.5. Population and Sample size

The plan to reach out to the min. 1200 participant. The total 302 response has been taken. The total population size decide for research is 300 noted by filtering the responses and start of research. The subset of this population has been divided into automotive and mobility sector, energy sector, infrastructure, Technology (IT/software/AI/ data analytics), education, medical, media and artiest, socialist and others. The sustainable future mobility is concern with ecological, economical and environment. Along with this social element have major impact. So, considering this all-sector participant has been added.

The various age group participants are targeted to take feedback to cover all generation to wise feedback. This group has given input on mobility sector outlook about the sustainability. The respective sector considered in these studies are as below.

1. Automobile and mobility - Automobile and mobility - The 25% population selected from the mobility sector to cover all group including vehicle technology group, service group, mobility group concern to the energy sector, battery technology, fuel technology.
2. Infrastructure
3. Government
4. Energy - The energy sector input has been captured to understand shift in the energy to make mobility sustainable.
5. Technology (IT/Software/AI/Data analytical)
6. Media and artist

7. Socialist (environmentalist, social worker, politics)
8. Commercial (banking, economist, Finance, insurance)
9. Education
10. Medical (professional related to medical)
11. Other

### 3.6. Participant selection

Since this study is around mobility, the mobility sector participant, sustainability expert and interdeciplane sector participant seleacted. The question and interviews are planned accordingly. In this reasech the participant selected from mobility sector and other sintersector. Since in this reaserch, all related sector instesction is to be study for sustaianable mobility. The major % of participant are selected from the mobility field with different experince and expertise. The other sector like energy, government, medical has been selected to get feedback. The majority of the feedback from other sector has been taken by visting offfice or by attaining the confernces, expo or meet. Sicne other sector are not about the context of research. The majority mobility filed feedbacks are taken by sharing link of google form.

The partticipant selected in mobility sector those working on current mobilitty and future mobility in varioous role, extertise and age level. Participant selection ffrom each group as below.

Automobile and mobility - 25% population selected from the mobility sector to cover all group including vehicle technology group, service group, mobility group concern to the energy sector, battery technology, fuel technology.

1. Infrastructure
2. Government
3. Energy - The energy sector input has been captured to understand shift in the energy to make mobility sustainable.
4. Technology (IT/Software/AI/Data analytical)
5. Media and artist

6. Socialist (environmentalist, social worker, politics)
7. Commercial (banking, economist, Finance, insurance)
8. Education
9. Medical (professional related to medical)
10. Other

**3.7 Instrumentation**

The google form has created to do take survey and collect data at one place. The same questions are printed and this use to take feedback from participant at confernce and expo. In current context majority google form are getting created and participant found security concern. So some participant are prefered to give feedback manually. This is one of the learning in this process.

**3.8 Survey and Data Collection Procedures**

The significant research done in are of future mobility is to reduce the emission and address the climate change action plan. The questions are prepared to do survey and collect feedback, The purpose of survey to capture the input on designed questions. The data collection is done around question designed. The data is collected through various methos. The data collected by creating google form and send link. This is practically feasible where participant aware about the subject. The effectively data collected in EV mobility conference, energy conference and by visiting intersectoral field offices.

In past research concluded that decorbanisation initiative has felt the need of the integration energy sector for energy sector. The government of India has felt need to establish the edicated multidisciplinary mission to facilate co-operative federatism.The governmenet of India inplimented extensive stake holder and interministerial consultation for end to end policy framework preparation to transform the mobility landscape. This has majorly focused on the electrical vehicle mobility aspects of

- Manufcaturing

- Specification and standards
- Fiscal intensives
- Overall demand creations and projection
- regulatory framework
- reserch and development

This focus of this integration to create policies at government policies. The purpose of this activities are to pay divident to rapidly urbanising India in decde time. The multi-disciplanry national mission on transformative mobility and battery has started in Inida in this the interministerial committee is established. The activities majorly focus on the electrical vehciel and sustainable approach is not found. So, based on this participant seleced from respective sector to get feedback. The research find that seach sector finding need of integration of respective sector.

### 3.9 Data Analysis

The total smaple has been analaye to undersatnd the current ongoing efforts effectrivity. The data analysis is done sector wise to understand each sector perspective. The statistical tools are used to analyse the data. The purpose of analysis to note the finding of survey and decide the proposal. In the process of the survey connect to 2000 no. of participant approximaetly to take input. About 85% respondent are aware about electrical vehciel developemnt as Future mobility. The awarness of other mobolity like MaaS ( mobility as a service), share mobility are neutral. Since this are the major mode of transporation in India. But responded considerting this as technology used in mobility to enable mobility acess. The 15% responded are aware about future mobility and sustaianbility efforts toward it. The major is awarness found in the automobile and mobility sector participant. Since this is there core working sector. The awarness of sustainable mobility is very good in energy sector and insfrasture as well.

#### 3.9.1 Participation of the intersection sector

**Figure 3.1 Sector wise participants**

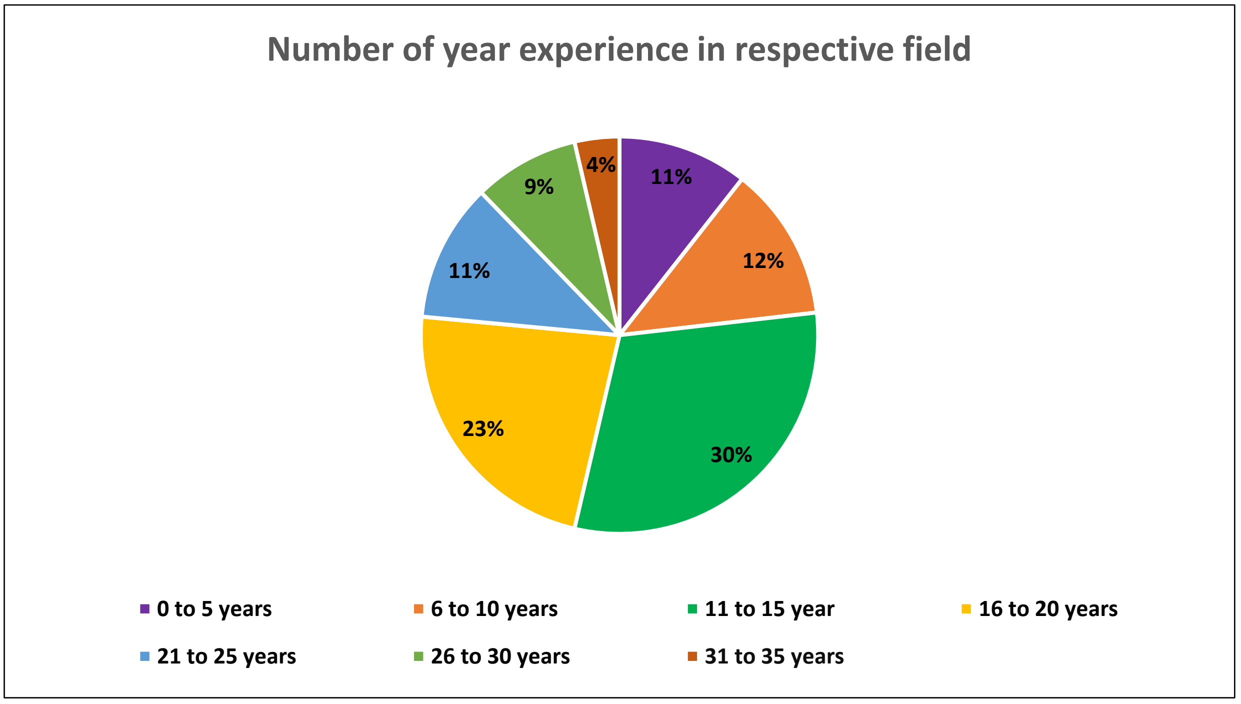

As per research purpose the intersection sector participant selected. As per literature and past research the achieving sustainability required the participation of all concern sector. The past literature has suggested that integration of the various intersection sector is required. So here captured major important intersection sector. Among this mobility sector is core sector and other are the intersection sector.

### 3.9.2 Participant experience in respective field for number of years

The 0 to 35 year of experience participant selected to take input. Since the 0-to-5-year experiences are participant are entering in the respective industry with input. The major participants are of 11 years to 20 years. Since this experience participant are working to build strategies for future mobility. The experience group of 20 to 35 is taken input taken. Since this group are steering investment decision and looking for transformation for benefit of next generation. This range of experinece has capture to get the all feedback include learing level feedbak, acuatul working level feedback and stategic level of feedback. Here not differentiating experince level input but taking as input reach to defined research level input.

At time of feeback complete range of experince participant, undrestood that all expericne level particiapant are looking for sustainable defination.

**Figure 3.2 Sector wise participants age group**

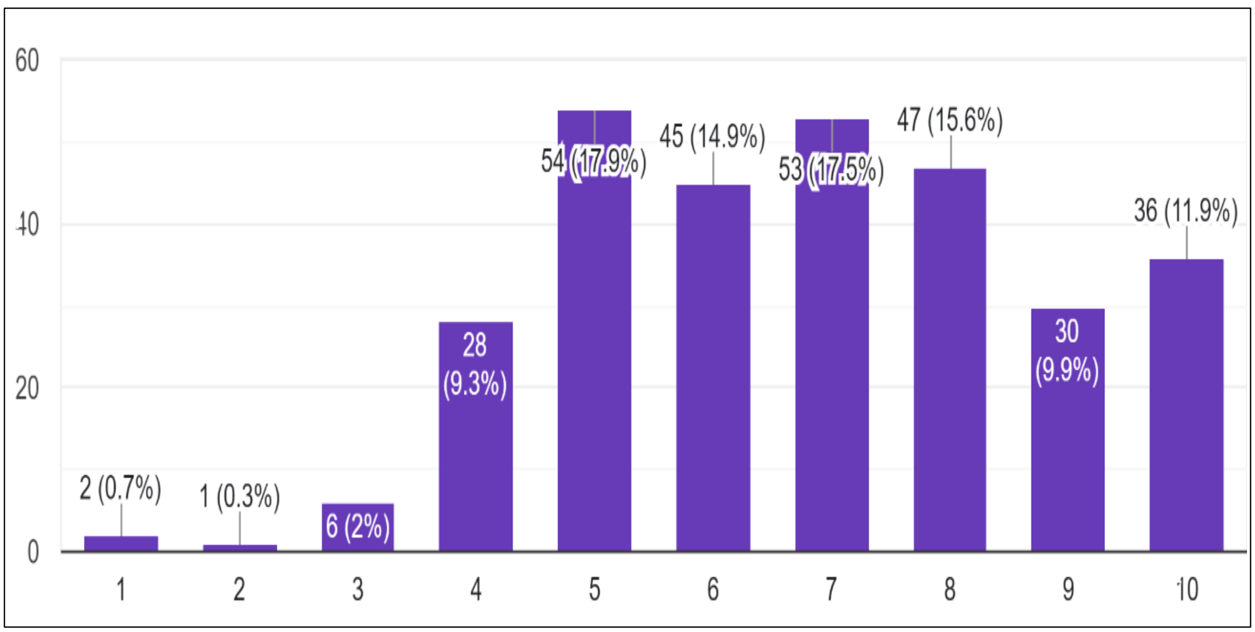


### 3.9.3 Decarbonization effort in India and awareness

The purpose of taking input on this point is to understand the awareness of the respondent regarding decorbanisation. In India various action are taken under decorbanisation initiative and year wise milestone defined. The initiative takes to decarbonize the major responsible sector. Among this the participants are linking electrification of the mobility sector and emission related to tail pipe. The participant from energy, education and energy background majority looking for end to end emission. So, respondent have given feedback considering the ongoing and projected efforts in field of electrical vehicle and energy together.

The 69% responded are agreeing that the ongoing and projected initiative will help to develop sustainable future mobility in India. This inputs are based on the current and projected electrical mobility developemnt initiatives. The responded considering that decorbamisation of tranpoart is sustainale future mobility. The 21.8% respondent are strongly agree on decorbanisation of the mobility in next 10 year in India.

**Figure 3.3 Decarbonization effort in India and awareness**



The 12% disgeeing and 15% are neutral. These respondent are refering sustaianble mobility beyond the decorbanisation.  This responded are majority from the automobility, energy sector, eduction and instrastructure. The around 50 % from education and 30% from infrastructure are disagree. The disgreemnet % of other sector is less than 10%. As per this input, the education and infrasture sector working on this and understood the sustainable mobility is beyond decorbanisation. The neutrals sector are infrasturecture 44%, social 48%, commerical 30% and medical sector 30%. Since this sector are looking for next level of initiative orther than decorbanisation to make future mobility sustainable.

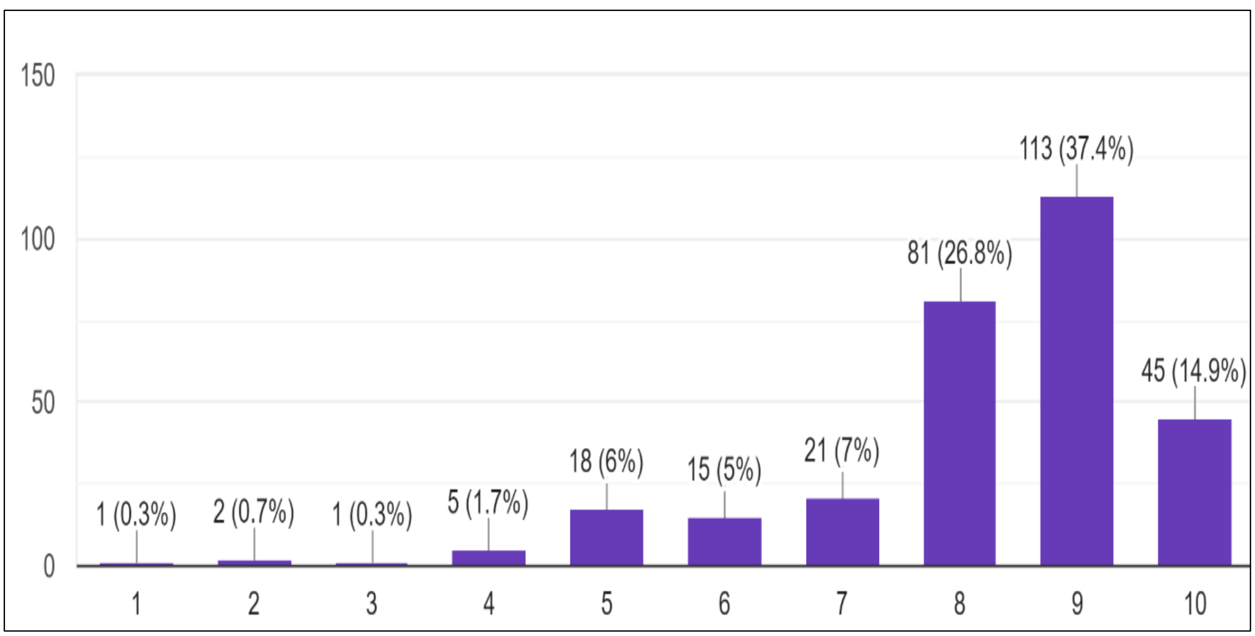
The input taken on “ongoing and projected decorbanisation intiatives will help to develop sustainable future mobility in India ine next 10 year”

### 3.9.4 Scope of Future mobility for sustainability

The 91% responded looking for future mobility which beyond emission reduction. The responded looking environmentally friendly mobility rather than decarbonize mobility. The 91% respondents agreed that environmentally friendly, safer, accessible, affordable, reliable, efficient and socially desirable are scope of sustainable future mobility. The 6% respondents are neutral on the scope of sustainable future mobility. The remaining 3% respondents are not agreed on this scope. These respondents would like to understand sustainable future mobility in detail. The 69.10 % respondent has rated this scope on scale of 8 to 9 and that scale toward strongly agreeable range. As per this the future mobility scope should include environmentally friendly, safer, accessible, affordable, reliable, efficient and socially desirable. As per this scope the sustainable future mobility required other sector involvement than mobility sector.

"The scope of future mobility is environment friendly, safer, accessible, affordable, reliable, efficient and socially desirable"

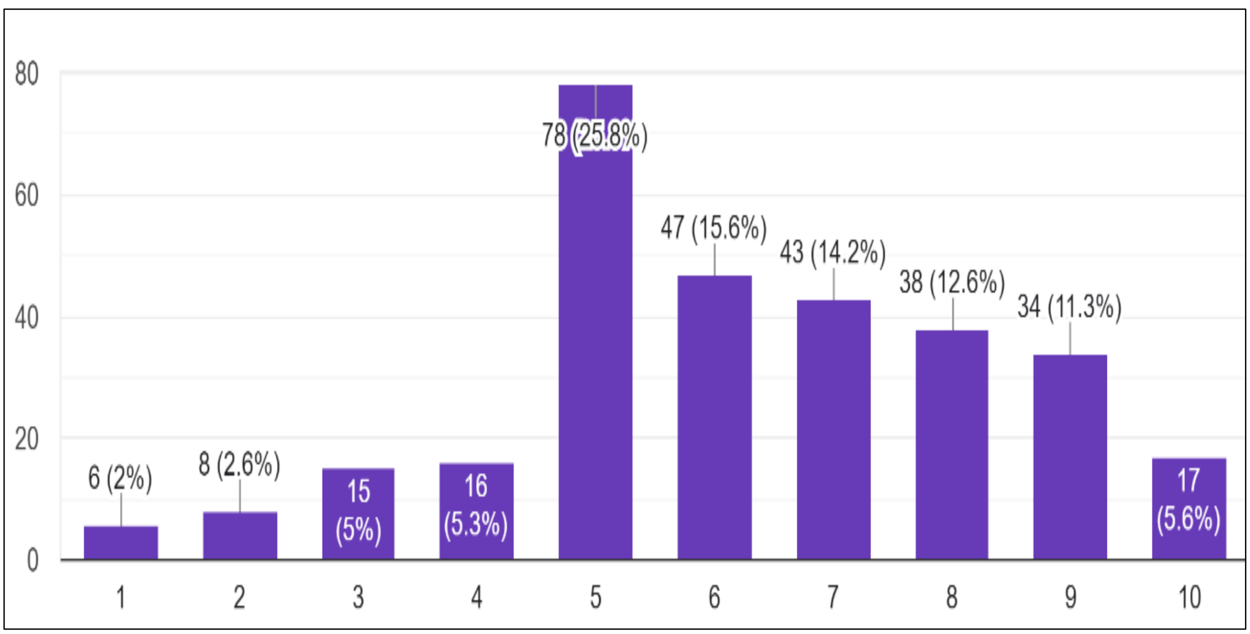
**Figure 3.4 Scope of future mobility for sustainability**



**3.9.5 The Current and projected efforts to develop sustainable future mobility are enough to develop Sustainable future mobility in India (future mobility refer here – electrical vehicle, mobility as a service, connected car, autonomous vehicle**

At present mobility megatrends such as alternate fuel powertrain, electrical mobility, connected car, mobility as a service (MaaS) and autonomous vehicle are popular are getting discussed in forums. This are part of the future mobility. 25.7% respondent are neutral that this will help to develop “sustainable future mobility” or not. The 14.90 % respondent are disagreed. The 59.40% respondent are agreed but do not strongly agree. The respondents agreed that the current and projected efforts are there to develop the “sustainable future mobility”. The response distribution here from agree to strongly agree is getting declined. The respondents are agreeing that there current and projected effort toward future mobility. But on sustainability of future mobility the respondents are not strongly agreed.

**Figure 3.5 current and projected efforts to develop sustainable future mobility**



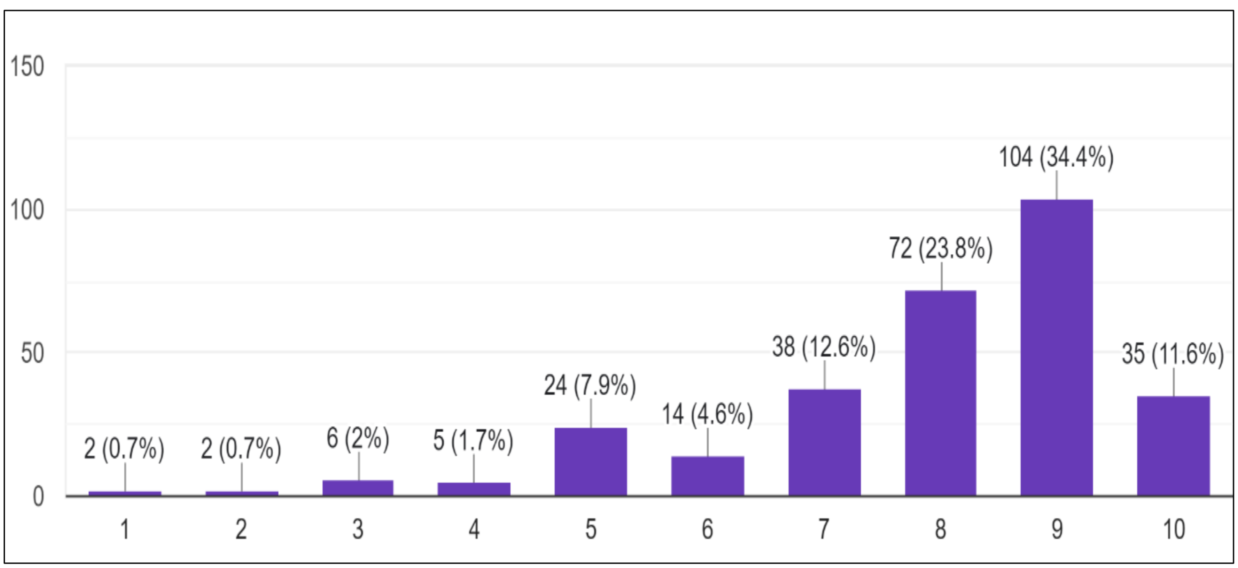
### 3.9.6 Quality of life with sustainable future mobility in India

The respondents are positive on the quality of life with sustainability. 87.00 % respondent are agreeing that quality of life will improve with sustainable future mobility. Whereas 7.9% respondent are neutral on this point and 5.1% respondent not agreed. The 87.00 is very strong indication to take quality of life is one the important element to work on "sustainable future mobility". So, the sustainable future mobility evaluation can be drive taking this is one of the important bases. At present the narrative for future mobility is to reduce the emission and to address the climate change. Along with this quality of life can be add as strong narrative.

The scale 8 to 10 is toward strongly agreeable. 69.80 % participants are strongly agreeing on improvement of quality of life with sustainable future mobility. The 46 % participant are agreeing on scale of 9 and 10. The participants are understanding sustainability future mobility benefits. The definition of quality of life is evolving in India. Here, the consideration of quality of life are related to the mobility. 87 % response is indicating the strong inclination of respondents toward the sustainable future mobility.

The quality of life will be improved with implementation of sustainable future mobility in India

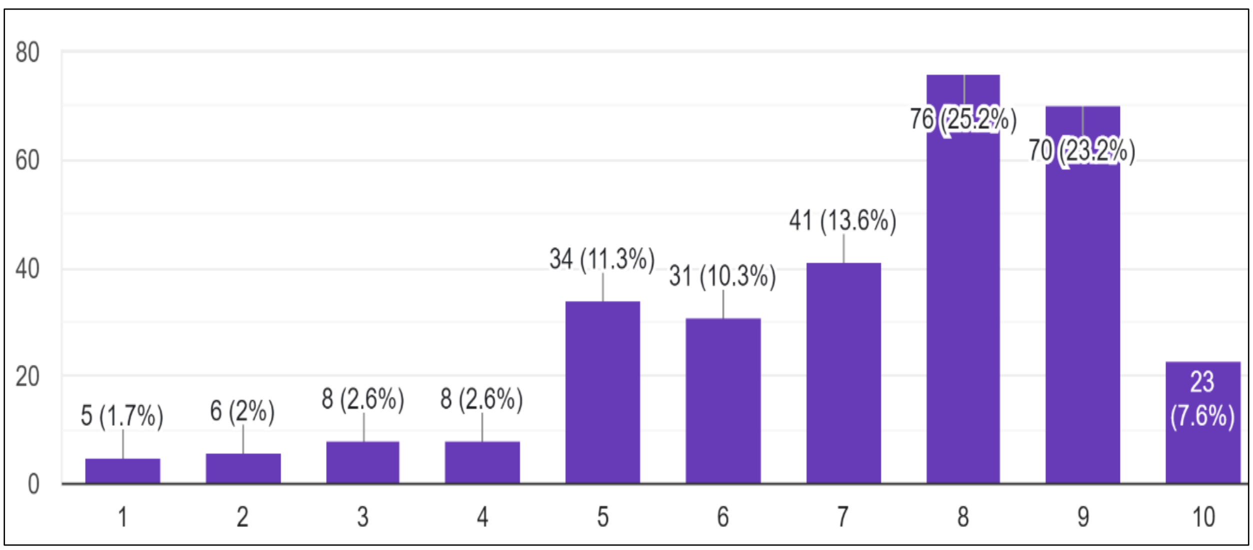
**Figure 3.6 Quality of life with sustainable future mobility in India**



### 3.9.7 Cost of life with adaption of the sustainable mobility in India

The cost of life is one of the important elements considered by the people before adaption of any change or technology. The 95.3% respondents are agreeing that by introduction of the "sustainable future mobility" the cost of living will be increase. In India the cost of living is one of the important measures to consider introduction of any new technology or change. So as per current trends in the future mobility vehicle like electrical vehicle, connected car, MaaS (mobility as a service) the cost of this technology is higher and people not finding competitiveness in price of future mobility. So, adding appropriate efforts to spread awareness regarding price competitiveness of the future sustainable mobility technology. At present in current scenario the sustainable technologies are costlier because of the rate of production and advance development stage. Even though respondent looking for the sustainable future mobility the concern of high od cost of living is there. So, bringing sustainable mobility at competitive price is required. The cost of living will increase due to the adaptation of sustainable future mobility in India.

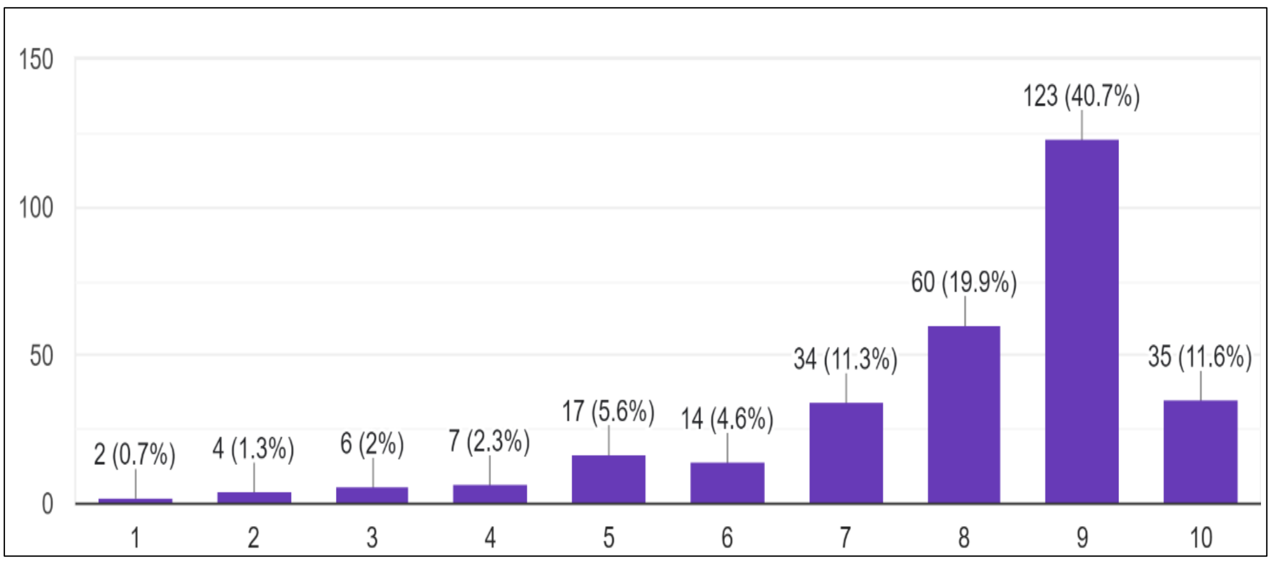
**Figure 3.7 Cost of life with adaption of the sustainable mobility in India**



### 3.9.8 The lower total cost of ownership and increased affordability of mobility will help for faster sustainable future mobility in India.

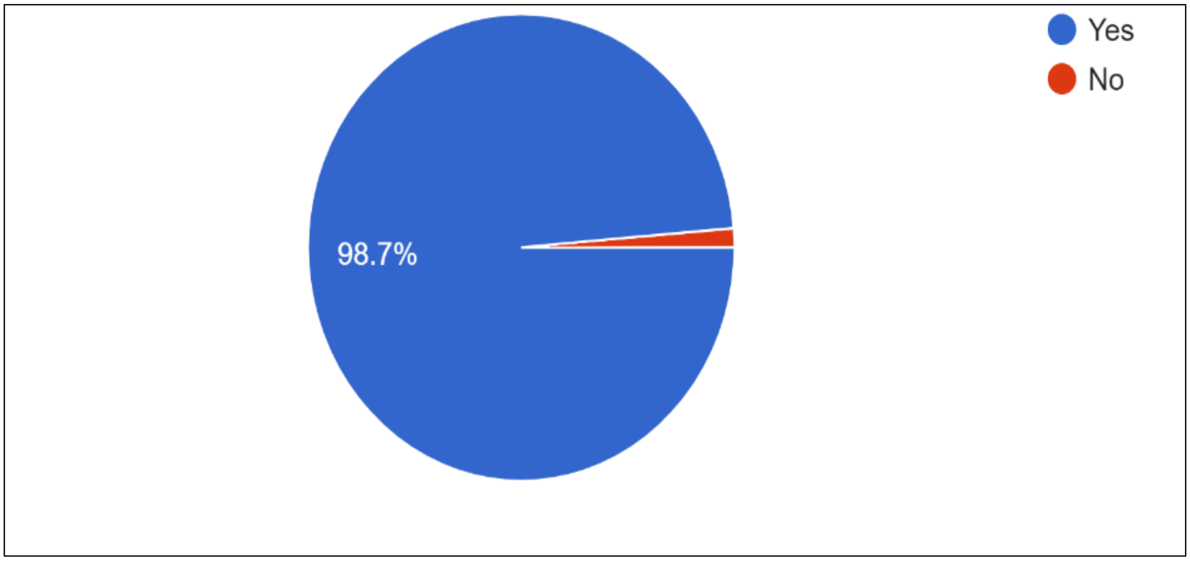
The respondents are concern about the increase in cost of living due to sustainable future mobility. But ready to accept the sustainable future mobility with lower total cost of ownership and increase affordability. The current analysis of the electrical vehicle price shows the electrical vehicle price high compared to conventional vehicle. But this needs to look into perspective of the total cost of the ownership. The 88.10% respondent are ready to accept future of mobility with lower total cost of ownership and increase affordability. The lower total cost of ownership and increase affordability will help for faster implementation of the sustainable future mobility. The lower total cost of ownership and increased affordability of mobility will help for faster sustainable future mobility in India.

**Figure 3.8 the total cost of ownership and affordability of mobility**



### 3.9.9 Success of "Sustainable future mobility" in India requires contributions of other than automobile and transport, if yes respond on below

**Figure 3.9 contribution for success of the future mobility**



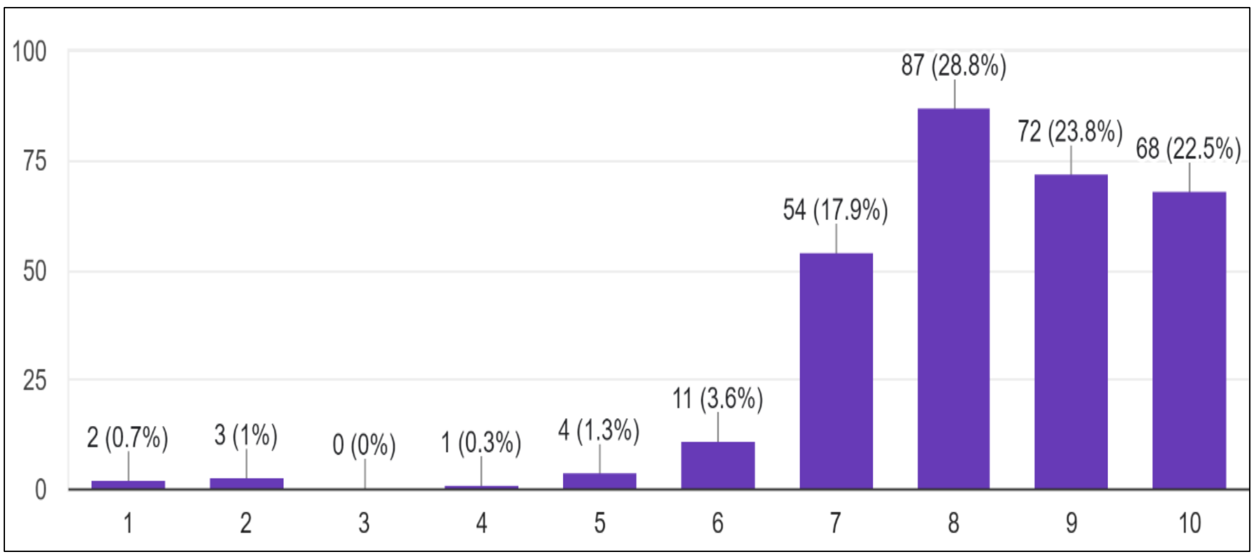

These responses are taken as the purpose of the research to analysis role of sectors other than mobility for sustainable future mobility. The 98.7% respond agree contribution of another sector than mobility required for success of the "sustainable future mobility". This is on the important. Since current mobility is motor vehicle centric and as pet his data moving away from motor centric mobility is required. In past, the mobility understanding is about the automobility, transportation. The major focus for sustainability is to reduce greenhouse gas emission release by automobile. So, the tailpipe emission reduction was prime target.

There was not focus on other contribution factors than the automobile and transport. Since various mobility technologies are evolving and getting popular respondent are finding the contribution of the other than automobile and transport for sustainable mobility. The electrical vehicle introduction is getting traction in India. So, majority of the respondent responding toward the electricity for the mobility rather than fossil fuel. The respondents are experiencing the current evolution the mobility mode like mobility as a service include mobile application base booking of vehicle and other shared mobility application. This is giving understanding to users regarding the use of technology other than the only automobile and transportation. 98.70 % respondents are aware that other contribution is important to make mobility sustainable. This data is very much important to expedite sustainable mobility implementation.

#### 3.9.9.a. Energy sector

The major decorbanisation transformation is happening at energy sector. Since energy is one production is one of the sources of greenhouse gas emission. In future mobility of electrical vehicle energy is going to play bigger role to replace fossil fuel. So, requirement of energy is increasing. The respondent concern about energy. Since this is one of the important sectors to support the future mobility electrical vehicle. The respondents are concern about current energy sector emission level and carbon intensive input source. The participants are ambitious about the renewable energy resource for generation of electricity. As per dependence of the mobility on energy sector is well understood.

**Figure 3.10 energy sector contribution for success of the future mobility**

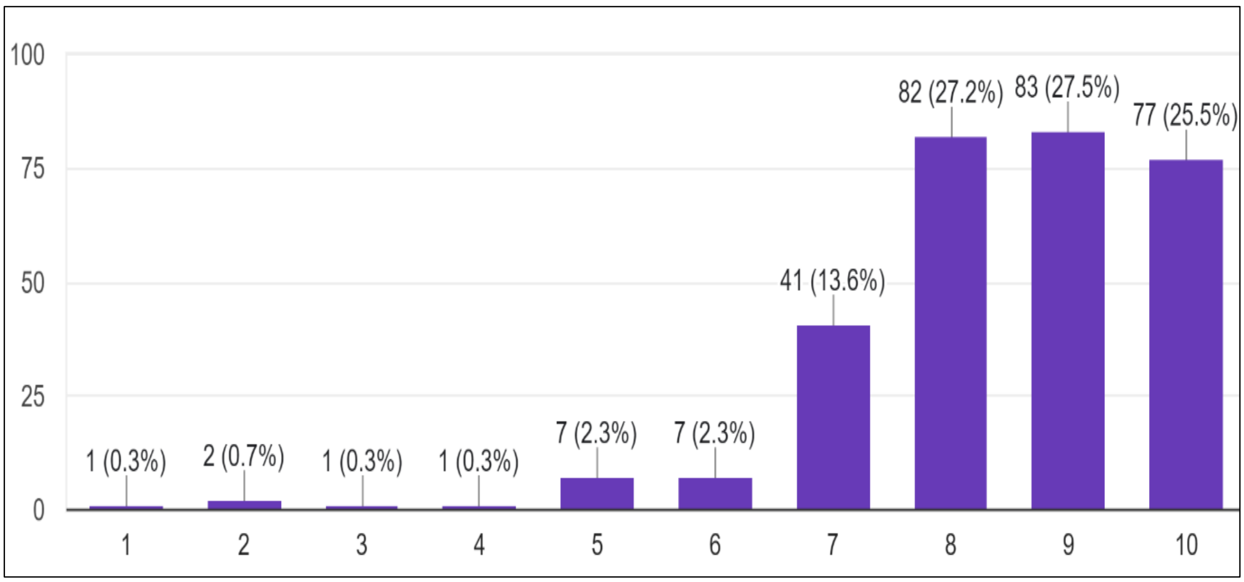



The 96.60 % responded agreed that contribution of energy sectors is required for sustainable future mobility. The 1.3 % respondents are neutral. The respondents are aware about the current electricity generation sources. The current major energy sources use to power the automobile or transport in India is fossil fuel. The respondents are aware about current electric vehicle introduction for the greenhouse gas reduction. The current sources used for energy's are carbon intensive and respondent aware about this. So, for electric vehicle the energy is one of the important elements for future sustainability mobility.

### 3.9.9.b Human behavior

It's one of the important elements to move toward the sustainable mobility. The 96.10% participants are agreed that human behavior one of the important elements to implement sustainable. The 80.20% participants are agreeing the contribution of human behavior on scale of 8-10. This is showing the strong contribution of the human behaviors. The 2.3% are neutral and 1.6% participants not ageing on human behavior contribution. The mobility is at central and driven by human behavior. So, the human behavior toward the sustainable mobility is important. This is the element is not required technology but required the demonstration to accept the change.

**Figure 3.11 human behavior contribution for success of the future mobility**

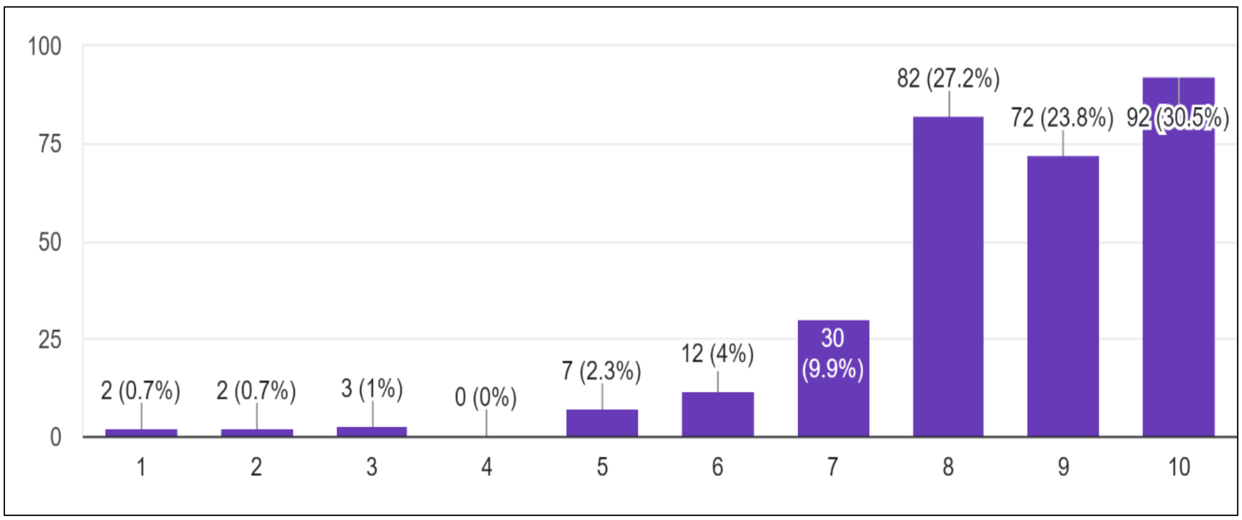



The mobility is one of sector where human behavior has strong contribution. This contribution has involved the pride of mobility purchase, ownership pride, social image, shifting from personal pride vehicle to the mobility as service. The human behavioral shift is one of the important elements to go for alternative mobility solutions. The human behavioral studies are important to bring sustainability aspects in future mobility. As per participants feedback the human behavioral has highest contribution.

#### 3.9.9.c. Government policies and schemes

The future mobility is emerging field. So, to accept this change government policies and scheme are required. So, government are going to play important role. The 97.70% participant are agreeing that government policies and schemes are important. The 81.50% participants are strongly agreeing the contribution on the scale of the 8 to 10. The 2.30% participants are neutral and 2.4% participants not ageing on contribution on the contribution of the government policies and scheme. The participants are linking these policies for mobility and allied for sustainability. At present in India some policies are implemented and which in favor to increase sale of electrical vehicles. The government policies are rolled out to support the manufacturing of new technology vehicle in India. It includes the subsidiaries for localization of the electrical vehicle in India.

**Figure 3.12 Government policies and schemes contribution for success of the future**



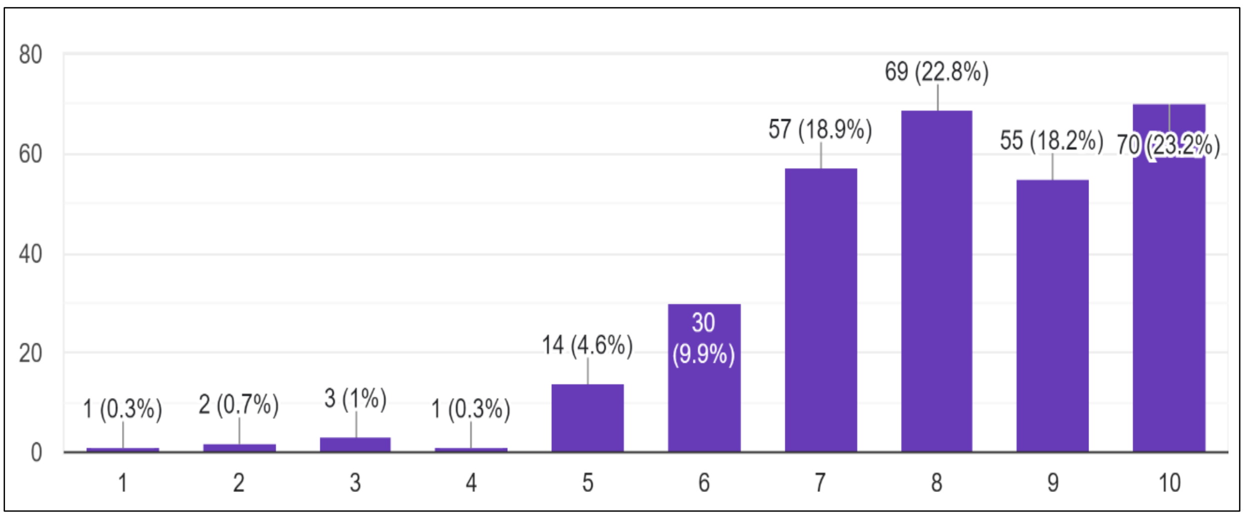

**mobility**

The government polies are very much important for introduction of the new technology. Since the standards, regulation, taxes are not existed and evaluation of that in favor of new technology will help to shape. The new technology required the common or public infrastructure and where government role is instrumental. The new technology needs the upfront investment and which is costlier at time of introduction. So, to compete new technology in market and meet total cost of ownership in comparison of the existing technology government schemes are required.

### 3.9.9.d. Mobility as a service (Public transport, shared mobility, on demand service)

The participants are agreeing that on mobility as service for sustainable mobility. The participant expresses that human behavior and mobility technology like electrical vehicle integration will help for sustainability. The 93% respondents agreed that mobility as service will help for sustainable mobility. The response on the scale of 8 to 10 is 64.40%. The 4.60% responded are neutral. The 2.30% respondent are on the disagreed side. The major thought of respondents that reduction in number of vehicle trips will reduce the greenhouse gas emission. The respondent at time of response considering that mobility technology like zero emission vehicle and energy source for mobility are sustainable.

**Figure 3.13 Mobility as service contribution for success of the future mobility**

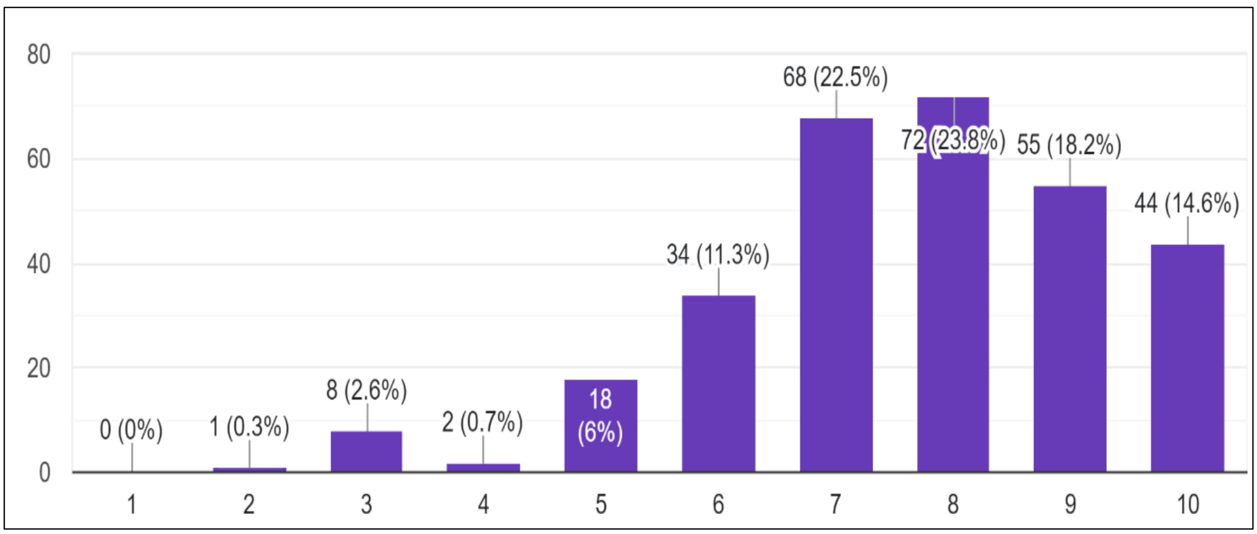



In India the public transport and shared mobility are important mode of transportation for people. These modes of transport are important for movement of the people as per their convenience and affordability of mobility. In India these modes of transports are exist before the mobility of mobility as a service mega trend. In India share mobility has popular to reduce passenger the per kilometer cost reduction purpose and increase affordability. The greenhouse gas reduction perspective is getting evolve now. The accessibility of mobility is challenge in public transportation. The on-demand mobility is toward premium mobility service.

### 3.9.9.e. Commercial (Banking, Economics, finance and Insurance)

The 90.40% respondent are agreed that commercial sector have important role in sustainable mobility. The responded are considering that future mobility is emerging technology and commercial sector important to bring the investment, add good pricing mechanism and baking support. Since this sector is new the insurance mechanism is not yet established and mobility required good insurance back up. So, participants are taking this in considering this linkage of the commercial sector. The commercial sector respondents are believing that commercial sector have power to implement the sustainable mobility by bring this in business focus area.

**Figure 3.14 Commercial sector contribution for success of the future mobility**

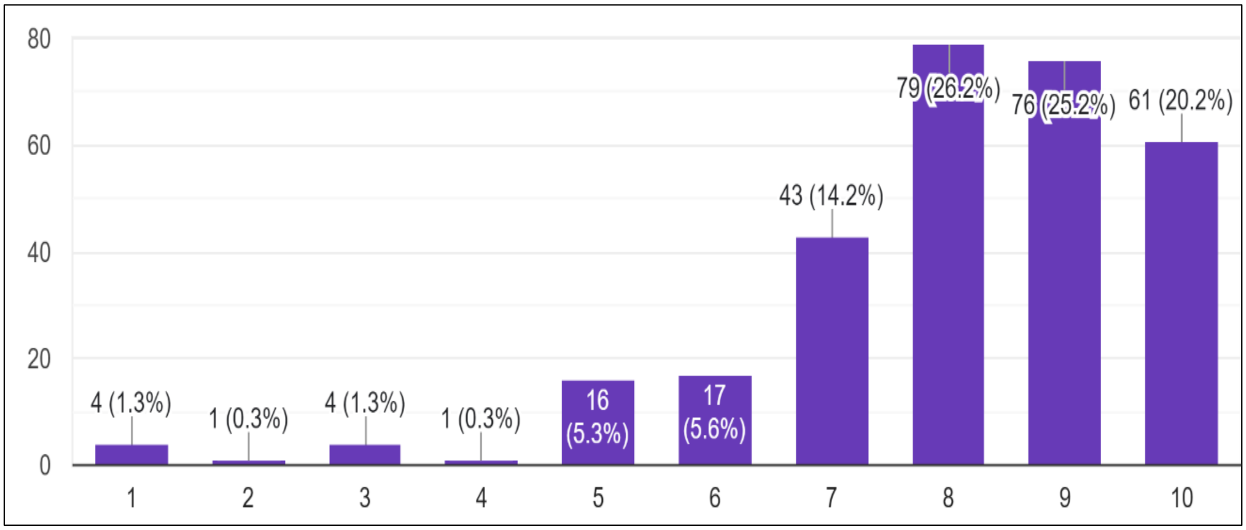



The agreeing responses on scale of 6 to 8 is 70.10%. The 6% respondent are neutral on contribution of the commercial sector for sustainable mobility. This indicates the respondents agreeing the contribution but not strong agreeing. The technology introduction required the commercial sector contribution to finance the research activities, capital investment on technology infrastructure. Since sustainable future mobility is at initial stage of introduction the respondents are not toward strong agreement. The initial technology introduction and government subsidiary required contribution of the commercial sector. At technology introduction phase government intervention is requires.

### 3.9.9.f. New technology – digitalization, Artificial intelligence

The 91.4% participants agreed that technology is important to integrated along with mobility sector for sustainable future mobility. The 45.40 % participants are strongly agreed the on contribution of the new technology on scale of 9-10. The 5.5 % participants are neutral on contribution of the new technology for sustainable future mobility. The participants are referring here the various digital platform to implement the mobility as service, share mobility. The autonomous vehicle, vehicle safety are the technologies for mobility and this will help to implement sustainable future mobility. The participants are agreeing that independent efforts in mobility sectors will not help for sustainable mobility. So, this is one of the important sectors to integrate.

**Figure 3.15 new technology contribution for success of the future mobility**

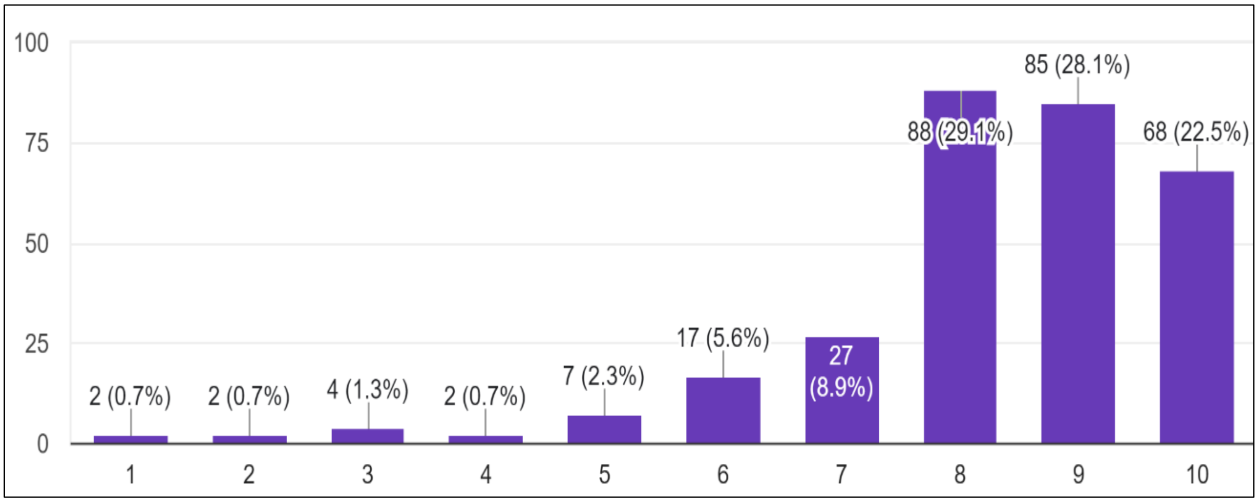



The technologies other than automobility are getting introduce in mobility sectors. In past mobility is around drivetrain technology and limited with other technology. The presence of new technology like digitalization, artificial intelligence is visible at present in mobility. The trends like mobility as service, vehicle safety automation and other application are example of new technology contribution. But participants are agreeing that moving forward much more contribution of new technology is required for sustainable future mobility.

### 3.9.9.g. Infrastructure and urban development

The 94.2% participants are agreeing that the infrastructure and urban development sector contribution is important for sustainable future mobility. The 50.60% participant are strongly agreeing the contribution of the infrastructure and urban development. The 2.3% participants are neutral. The participants are referring here infrastructure required for electrical vehicle, infrastructure required for alternate fuel technology, infrastructure to build technology platforms, infrastructure required to build the sustainable energy required for mobility sector. The participant has understood that mobility independently cannot bring sustainability. So, in this process the infrastructure sector has important contribution.

**Figure 3.16 Infrastructure and urban development contribution for success of the future mobility**

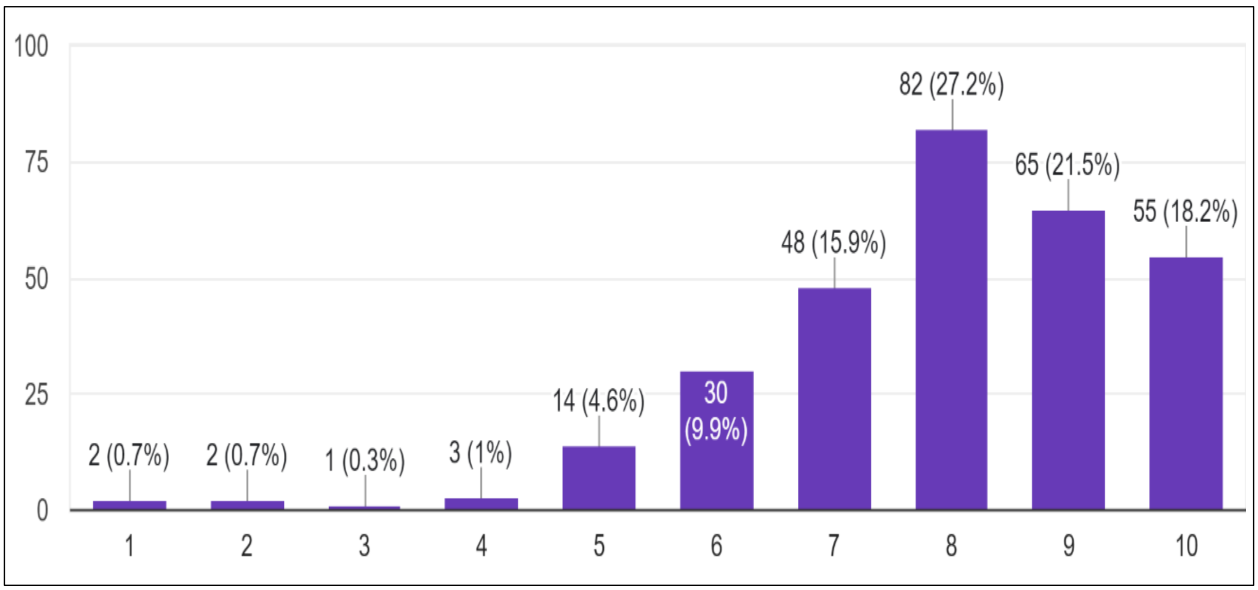



The participants agreeing the contribution of the infrastructure along with mobility development. The mobility by own cannot perform without he adequate and important infrastructure. The participants are discussing the current challenge of charging infrastructure for adoption of the electrical vehicle. The participants are understanding the need of faster urbanization. So, the urban development planning is required sustainable mobility concept. The infrastructure is prime along with mobility technology for sustainable future mobility.

### 3.9.9.h. Education sector (formal and non-formal education)

The 94.20% participants are agreed that education sector have contribution to make future mobility sustainable. The 66.90% participants are agreeing contribution of the education sector on scale of 8 to 10. The 4.60% participants are neutral. The education sector can bring transformation by the formal and informal educational system. Since education sector is source of the technical and non-technical details. This sector can embed the importance of the sustainable mobility.

**Figure 3.17 education sector contribution for success of the future mobility**

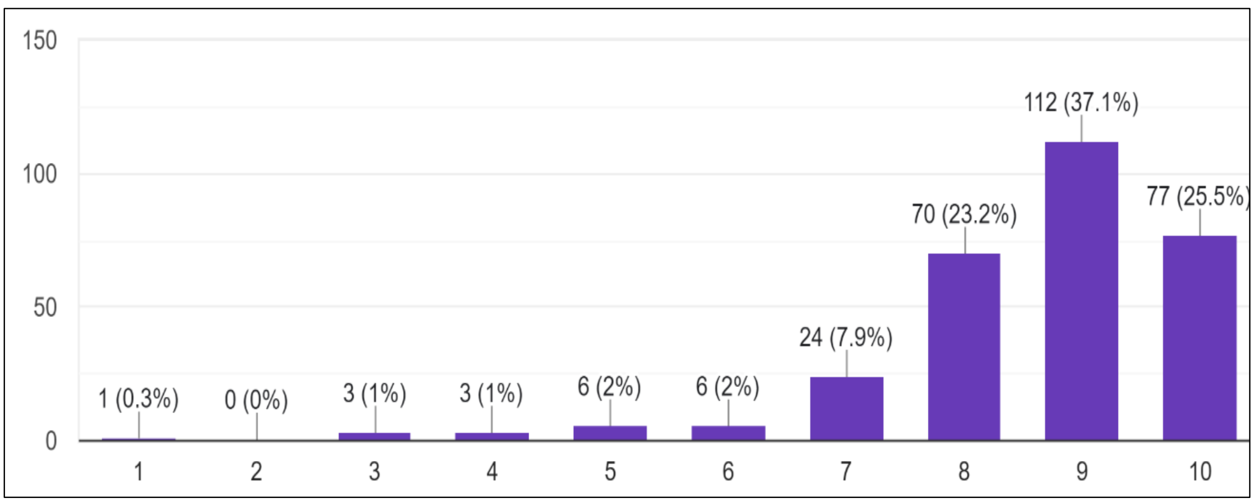



The education sector is important for sustainability drive. In include research, development and spread awareness of sustainability. There is drive for sustainability in India with involvement of formal and non-formal education. But at present there is limited channel for formal and non-formal education on sustainable future mobility. The education sector is important to for sustainable mobility technology introduction as well as to do the innovation required for implementation. At education sector is required adequate commercial sector support and at present there is limited support to develop and implement the sustainable future mobility.

### 3.9.9.i. All the above sectors together

In above data participant responded individual sector contribution in future sustainable mobility. The 95.70% participant agreeing that all sector together contribution required to develop the sustainable future mobility. The 85.80% participants are agreeing the requirement of integration all sector together. The 62.60% participants are strongly agreeing on scale of 9 to 10 on contribution of all sectors together for sustainable future mobility. The 2% participants are neutral and 2.3% not agreeing. The participants are responded considering the out of all sectors together for sustainable future mobility. As per this analysis clear that collective contribution of the energy, human behavior, government policies, technology, mobility as service, infrastructure, commercial sector, education is important in Indian context.

**Figure 3.18 all the above sectors sector contribution for success of the future mobility**

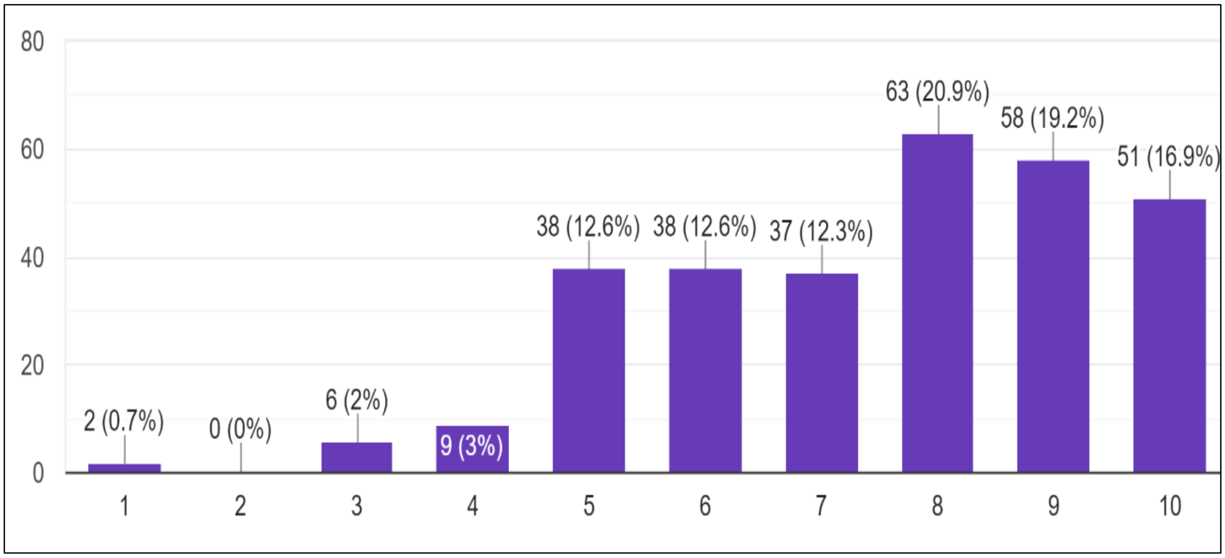



The participants are finding need of each sector contribution but along with that agreeing on the strong need of all sectors together for sustainable future mobility. The sustainable mobility is collective efforts of all together. The respondent responses are clearly indicating the requirement of collective contribution of all sectors together. The participants are finding the importance of all mentioned sector together. The mobility is pivotal to bring together all mentioned sectors by taking sustainability at central for future mobility.

### 3.9.10 In an Indian context sustainable future mobility need, faster introduction and implementation of new technology like clean energy, battery electrical vehicle, hydrogen vehicle

The 81.90% participants are agreeing that future mobility technology like clean energy vehicle, battery electrical vehicle, hydrogen vehicle’s faster introduction is required for sustainable future mobility. The 12.60% participants are neutral on this point. At present participant are able see the progress happening on the electrical vehicle but progress on clean energy and hydrogen vehicle is limited. The 81.90% participants are ambitious regarding this technology in India context and ready to welcome this.

**Figure 3.19 In Indian context Technology introduction for sustainable future mobility**

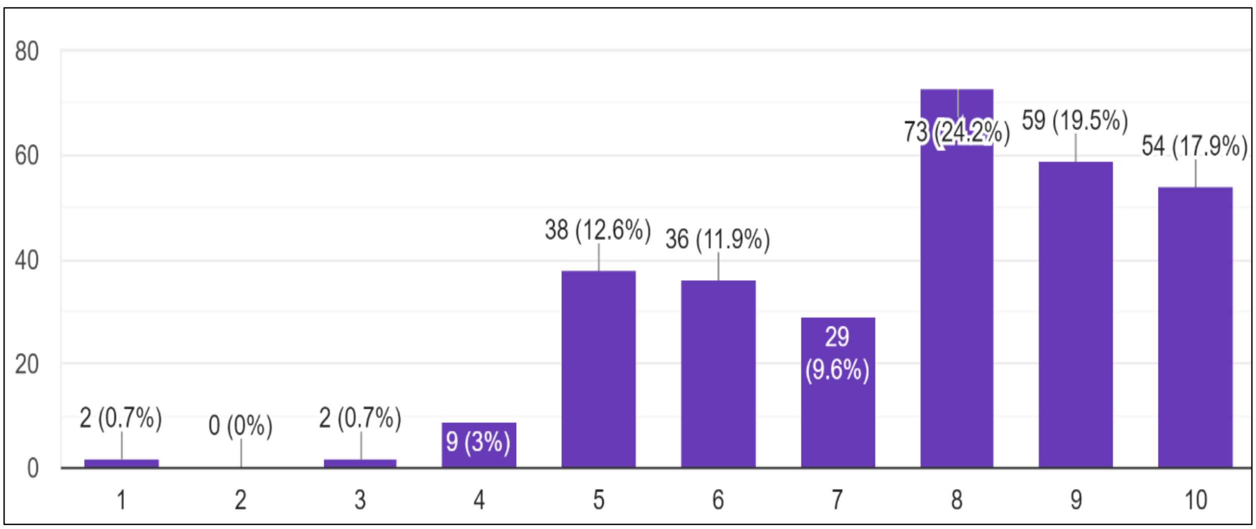



The participants are finding discussion and developments started in area of the clean technology, battery electrical vehicle and hydrogen vehicle. The participants are looking for faster introduction of this technology. The participants are very much positive to drive the sustainability. The participants are really concerned on the sustainability and important of mobility for same. In India this technology at nascent stage and much development does not happen. There is push in India for electrical vehicle and clean technology but limited development on hydrogen vehicle.

### 3.9.11 In an Indian context sustainable future mobility need, infrastructure development for electrical and hydrogen vehicle

The 83.10% participants agreeing that in Indian context push required on infrastructure development for electrical vehicle and the hydrogen vehicle. The 61.60% participants are strongly agreeing on the need of infrastructure development for electrical and hydrogen vehicle. The 12.60% participants are neutral and 4.40% participants disagreeing. The participants are very much concern about the electrical vehicle infrastructure and electrical infrastructure behind this. The participants are very much curious about hydrogen vehicle but highly concern about infrastructure required it. The participant at present looking at Hydrogen as the technology solution for the sustainable mobility

**Figure 3.20 In Indian context infrastructure development for sustainable future mobility**

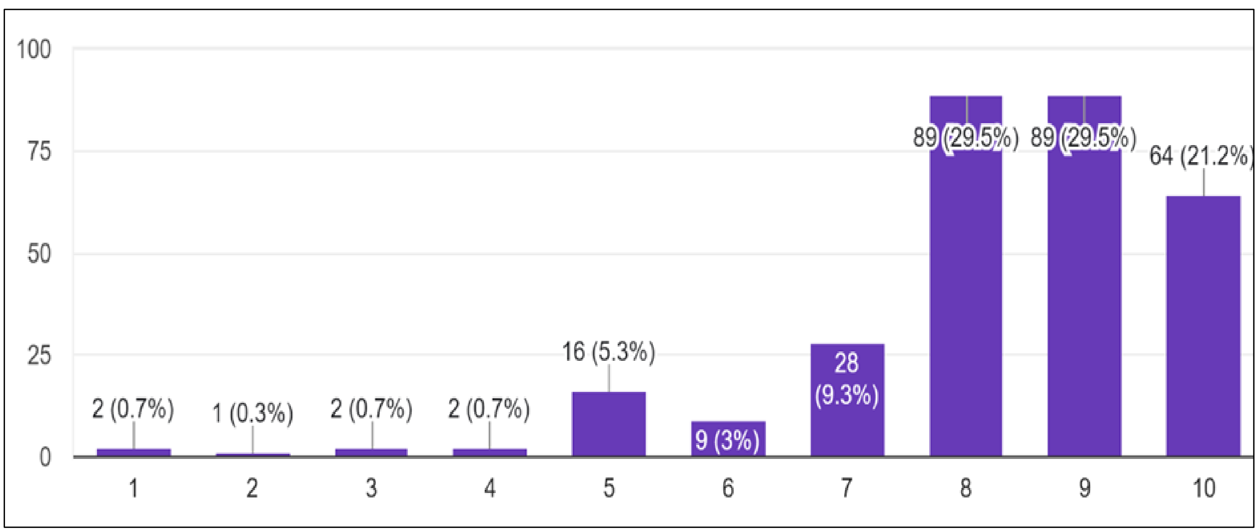



The electrical vehicle and hydrogen vehicle are evolving mobility technology. These technologies are not directly comparable with current technology to communize need of infrastructure. The infrastructure required for electrical and hydrogen vehicle is different than internal combustion dominant technology. The difference in the vehicle drive technology, fueling infrastructure technology and other unique. So, participants are looking for infrastructure development as prime mover for electrical and hydrogen vehicle development in India.

### 3.9.12 In an Indian context sustainable future mobility need, current mobility efficiency improvement and parallel introduction of new technology in phase wise with a defined timeline target

The 92.50% participant are agreed that efficiency improvement of the current mobility and parallel introduction of the new technology in phase wise manner wise manner with defined timeline targets help for sustainable future mobility introduction. The 80.20% participants are strongly agreeing on the scale of 8 to 10. The 5.3% participants are neutral and 2.40% participants disagreeing. The participants are aware about time required to bring the new technology like electrical vehicle and hydrogen vehicle and penetration time require for this technology. In this point in Indian context, parallel focus on technology like green biofuel and mileage improvement in current technology will help. So, the focus on the biofuel in short term up to electrical and hydrogen vehicle mass introduction is important. The participant looking for

**Figure 3.21 In Indian context parallel introduction of technology for sustainable future**



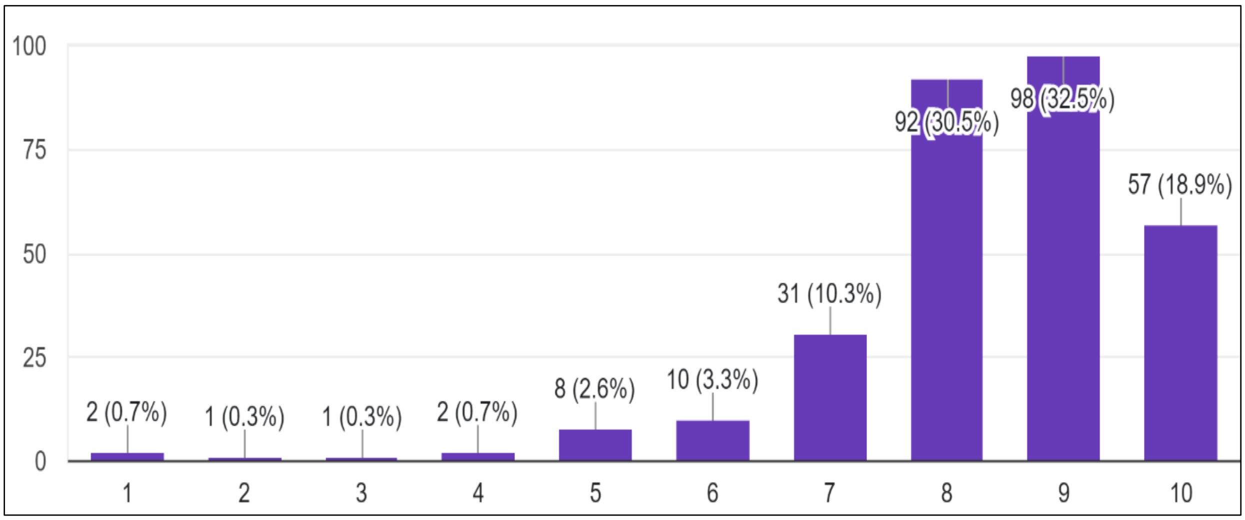

electrical vehicle or hydrogen as an alternative than replacement.

At present there is limited research in India on the advance biofuel and not in major focus area. So, bringing this are in focus for short term point and long tram point of view will help.

### 3.9.13 In an Indian context sustainable future mobility need, human behavioral change toward mobility, adaptability and usage

The 95.50% participants are agreed that human behavioral change toward adaptability and usage of vehicle is required in India context. The 81.90% participants are strongly agreeing on the scale of 8 to 10. The 2.60% participants are neutral and 2.0% participants disagree toward human behavioral change, adaptability and usage. Since at present the adaptability and usage in Indian context are not sustainable. Since without adaption and usage of future mobility in right way sustainability cannot be bring. The adaptability refers her is adaption of change in technology and right behavior to use it.

**Figure 3.22 In Indian context human behavioral change for sustainable future mobility**

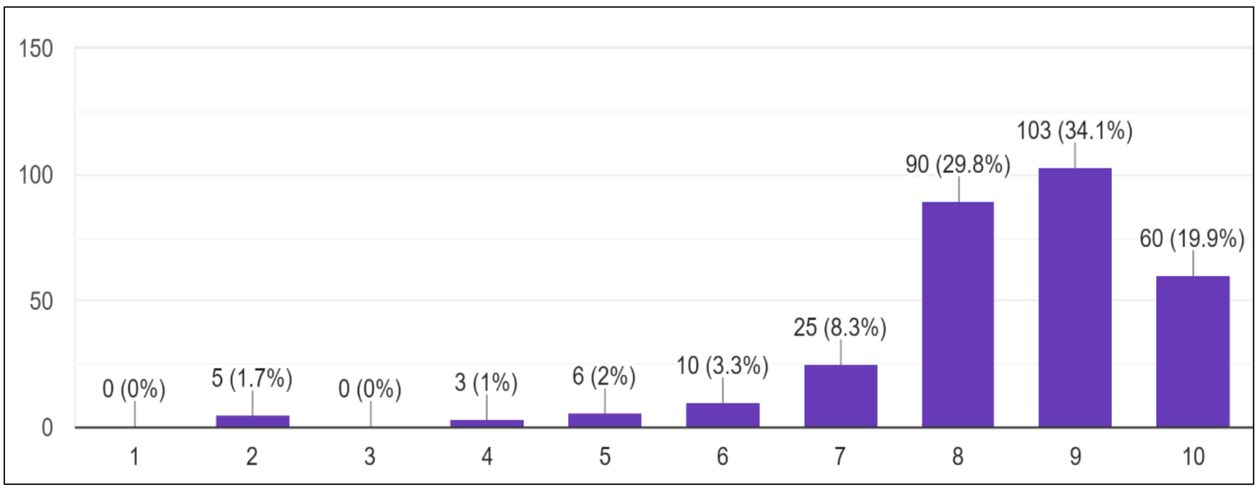



The mobility is one of sector where human behavior, adaptability and usage has strong contribution. The India is developing county and the diffusion of the mobility per 1000 people is still less compared to developing countries. There is wealth distribution gap in India and this have strong inclination on pride for person mobility. So due to ownership pride and social image shifting from personal vehicle and adapting the new mobility service have challenge in India. The human behavioral studies are important to bring sustainability aspects in future mobility. As per participants feedback the human behavioral has highest contribution.

**3.9.14. In an Indian context sustainable future mobility need, Technology accessibility and affordability for mobility by economical solutions**

The 95.40% participants are agreed that in Indian context the accessibility and affordability by economical solution is required. The 73.80% participants are strongly agreeing on need of technology accessibility and affordability for mobility by economics solutions. The 2.0% participants are neutral and 2.70% neutral. In India economical context technological accessibility and affordability of future mobility is needed for sustainable future mobility. Since in India economical technological solution adaption rate is higher and giving accessibility for same boost the rate of adoption.

**Figure 3.23 In Indian context human behavioral change for sustainable future mobility**

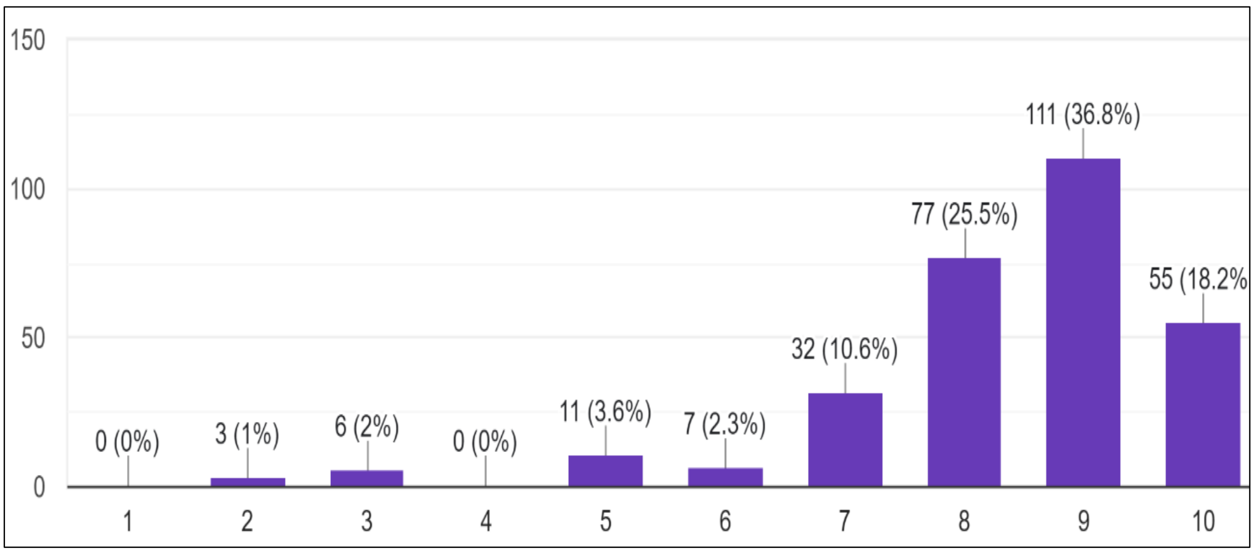



The accessibility and affordability to of technology to implement is required. The affordability and accessibility of technology at introduction phase is challenge due to the cost and initial investment. India as a developing nation the cost is one of the sensitive elements for accessibility and affordability with economical solutions. The new technologies are important for sustainable future mobility but to introduce same in Indian context the affordability and accessibility of new technology with economical solution is important. The participants are strongly supporting on this point.

### 3.9.15. In an Indian context sustainable future mobility need, customization of mobility within metro, urban, rural and to connect all these 3

The 93.40% participants are agreed that in Indian context need the customization mobility solution for metro, urban, rural and to connect these 3. The 80.50% participants are strongly ageing on the scale of the 8 to 10. The 3.6% participants are neutral and 3.0% participants disagreeing. Since in India geographical position of urban, rural and urban is different. So, bringing the standard solution will not work across all. The major focus to be given on this point. Since as transportation point of view this 3 have major contribution for greenhouse gas emission.

**Figure 3.24 In Indian context customization for metro, urban and rural for sustainable future mobility**

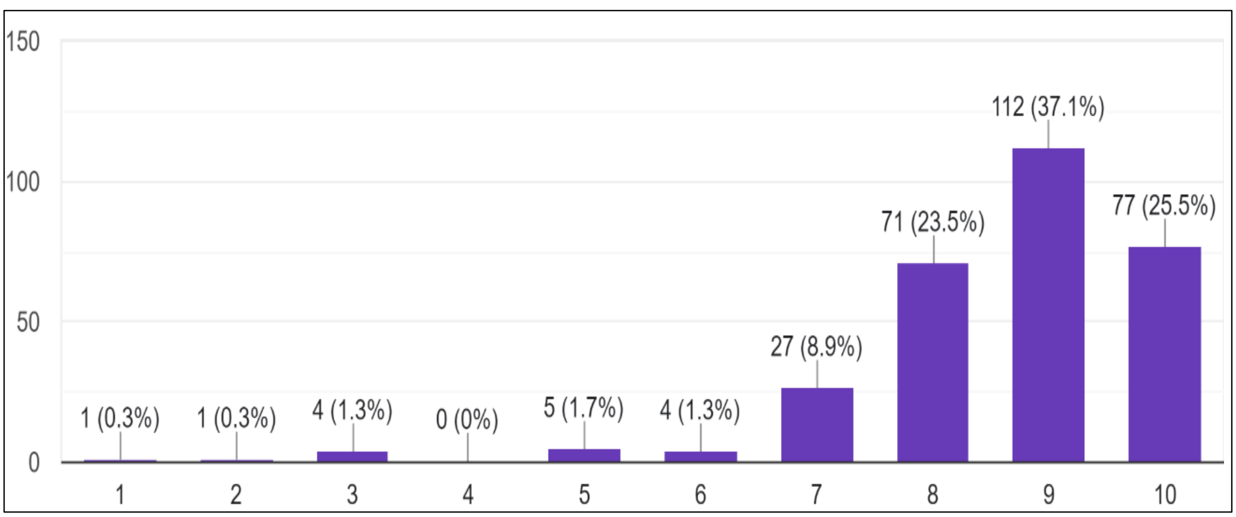



The India has distribution of metro cities urban and rural. The scale of economy and people distribution per square meter at metro, urban and rural is different. So, infrastructure at this level is differ. The implementation of same technology at every level is not feasible. The total cost of ownership of each technology not justifying equally at all regions. The customize technology at metro, urban and rural is required for sustainable future mobility.

### 3.9.16. In an Indian context sustainable future mobility need, focus government policies

The 96.30 % participant are agreeing that in Indian context focus movement polies are need for sustainable future mobility. The 86.10% participants are strongly agreeing on scale of the 8 to 10. The 1.70% participants are neutral and 1.90% participants disagreeing on the need of focus government policies for sustainable future mobility in India. These results are showing the strong need to focus government policies. At present there are policies which focusing on the electrical vehicle and decorbanisation of the energy sector. But the more focused polies required considering the sustainable future mobility. The India government has released the report in 2020 "India road map on Low carbon and sustainable mobility". But his is focusing on the decorbanisation of India transport sector. So, shifting focus from decarbonization of the mobility sector to sustainable mobility sector is required.

**Figure 3.25 In Indian context focus on government polies for sustainable future mobility**




The current available policies in India are focusing on sustainability with electrical vehicle. There are policies for decorbanisation of energy sector. The government policies are there which focusing on localization of electrical vehicles in India. But as per this data analysis its found that the focus policies for sustainable mobility are needed.

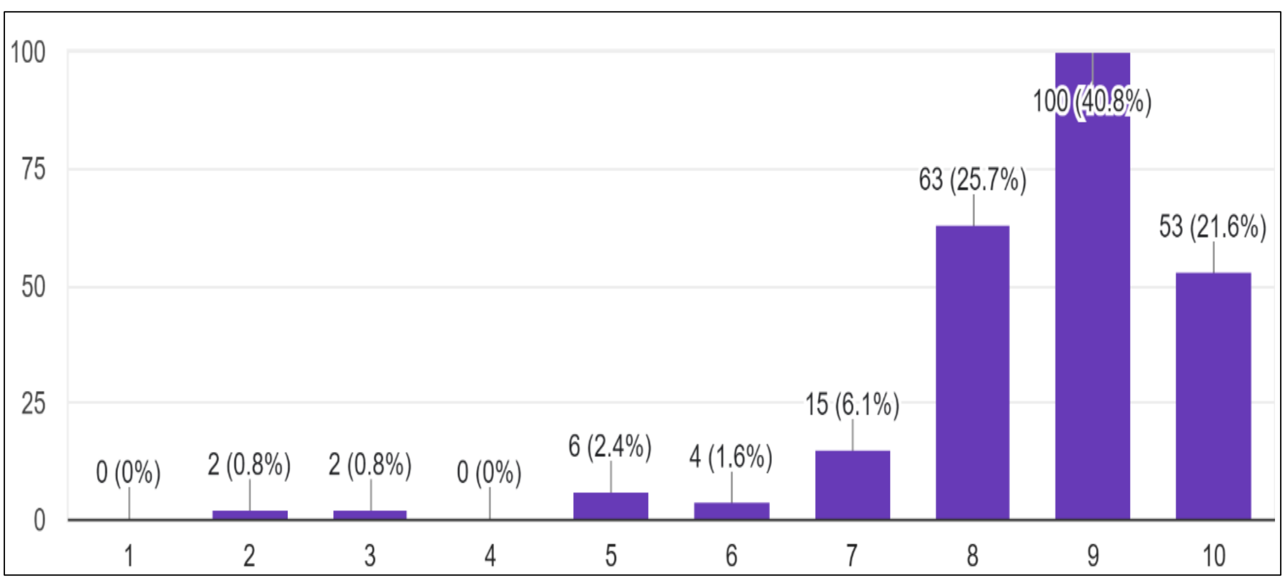
### 3.9.17. Sustainable future mobility can be implemented faster by comprehensive implementation of all above section 8.i. to 8.vii. point together

The 95.80% participants are agreeing comprehensive implementation of the

i. faster introduction and implementation of new technology like clean energy, battery electrical vehicle, hydrogen vehicle
ii. infrastructure development for electrical and hydrogen vehicle
iii. current mobility efficiency improvement and parallel introduction of new technology in phase wise with a defined timeline target
iv. human behavioral change toward mobility, adaptability and usage
v. Technology accessibility and affordability for mobility by economical solutions
vi. customization of mobility within metro, urban, rural and to connect all these 3
vii. focus government policies

The participant agreeing that independent efforts are going in future mobility area. But the comprehensive efforts are required for sustainable future mobility. There are limited effort to bring comprehensiveness in above mentioned.y

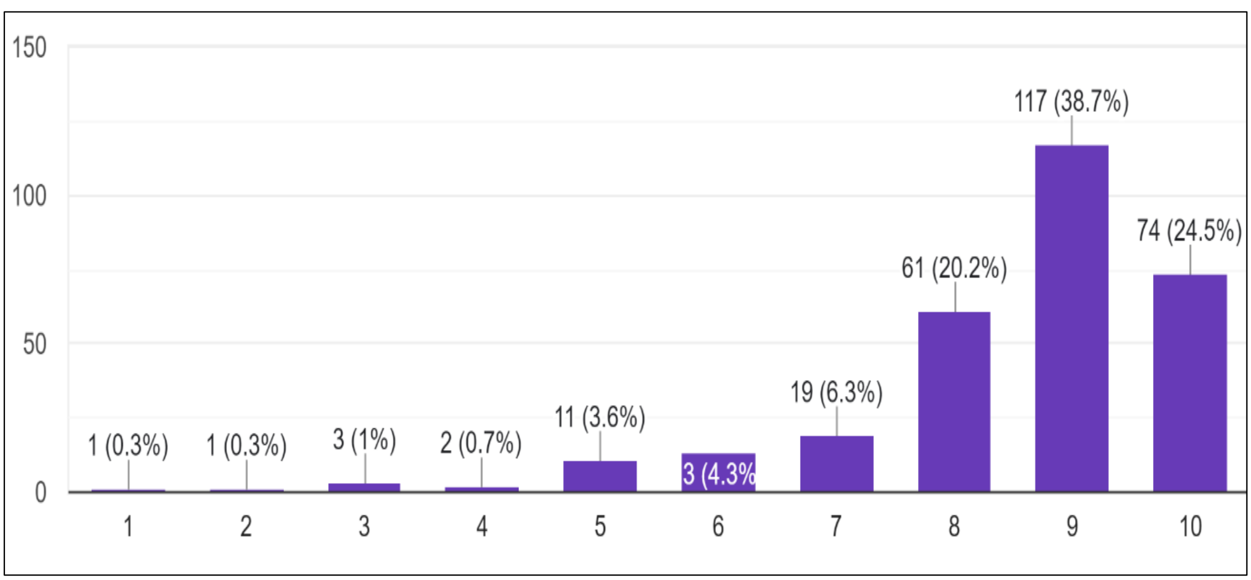
**Figure 3.26 In Indian context comprehensive implementation for sustainable future mobility**



### 3.9.18. Sustainable future mobility will help to boost social and economic development in India

The 94% participants ageing that along with improving quality of life, reduction in greenhouse gas emission, the sustainable future mobility will help to boost the social and economic development in India. The 83.40% participants are strongly agreeing on the scale of 8 to 10. The 3.6% participants are neutal and 2.3% particiapant disageeing on this.This shows that puttting efforts for sutaianbile mobility developemnt will help to boost scosial and economic development in India. The India have goal as nation to become $ 5 trilion. This can be strongly supported by sustaianble future mobility. The This will help to achieve one of the national goal. The participants are very much positive on the Sustainable future mobility. Since this will help for social and economic development. Even though participant earlier agree that sustainable future mobility increase the cost of living. Since mobility is at central implementing sustainable future mobility will help to boost social and economic goals.

**Figure 3.27 In Indian context social and economic development boost with sustainable future mobility**



### 3.10 Research Design Limitations

The mobility is vast field and reasech going on in globaly major on teachnical aspects in terms of futue mobility. The globally this field focusing on decorbnisation and urban planning. This reseach has been done in Indian context. The scope of future mobility is very vast and limitation to cover all in one reserch. The mobility is at central of rthe mobility and all concern sectrors are influcoing on it. So here in this research ocncerntrated is on identifying thesector for integration. The subject releted to how to integrate and what is the ingration of insection sector is not studied. This field in India is at necent stage. So, the data sharing by mobility field executve have limitation. There is diffent aspects of the sustainability in mobility field. The other mobility sustainability like vehicle tail pipe emission, life cycle assement emission, manufaturing emission, emission related to energy source in combination of the mobility powertrain are not completely focus here. Sicne there is limited to emission and very focused elements. The sustainability it self is big term and have limitation to cover complete sustaianability elements.

### 3.11 Conclusion

The research designed to capture the current scenario and response to achieve research objective. The participants are selected from various sector and with range of working experience. The responses are taken in context of the sustainable future mobility in Indian.

As per current and projected efforts studies found that the majority sustainability efforts in India to decarbonize future mobility. The 69% participants are agreed the ongoing and projected efforts are toward the decorbanisation of the future mobility. The respondents are agreed sustainable future mobility is beyond the decorbanisation of the mobility. The participants are aware about ongoing and future mobility technology. The scope of future mobility is beyond decorbanisation of the mobility. The scope agreed for sustainable future mobility include environmentally friendly, safer, accessible, affordable, reliable, efficient and socially desirable.

The participants are greed that the quality of life will be improve with the defined scope of sustainable future mobility. But equally aware that the cost of living will increase due to the sustainable future mobility. Since as per trend in market the sustainability is coming with premium. So, this is one of the fear points among the participants. The participants are ambitious to accept the sustainable future mobility with lower total cost of ownership and increase affordability.

The 98.70% participants are agreed for development of the sustainable future mobility required contribution other than mobility automobile and mobility sector. The more than 90% participants are agreed that comprehensive contribution of energy sector, human behavior, infrastructure, commercial sector, government policies and scheme, technologies (digitalization, artificial intelligence) mobility as a service, education sector required. The individual contribution of each sector is also more than 90%. So, this are major source to integrate for sustainable future mobility.

The in Indian context to develop sustainable mobility the faster introduction of the electrical vehicle, hydrogen vehicle along with infrastructure development. But the participants are agreed that introduction of future technology like electrical vehicle and hydrogen are time consuming. So long and short-term efforts to be developed to improve efficiency of the current vehicle along with new technology introduction. This will help to develop sustainable future mobility with right balance.

The human behaviors have major role to play. So, change in human behaviors toward future mobility adaptability and usage is important. The technological economical solutions and accessibility of the technology is required. The human behavioral change and technology accessibility can be brought by putting customize mobility solution for metro, urban, rural and connecting point for this 3. The government policies and scheme here play pivotal role to integrate and implement sustainable mobility. The 95% participant are agreed that the integrated comprehensive approach will help to implement sustainable future mobility.

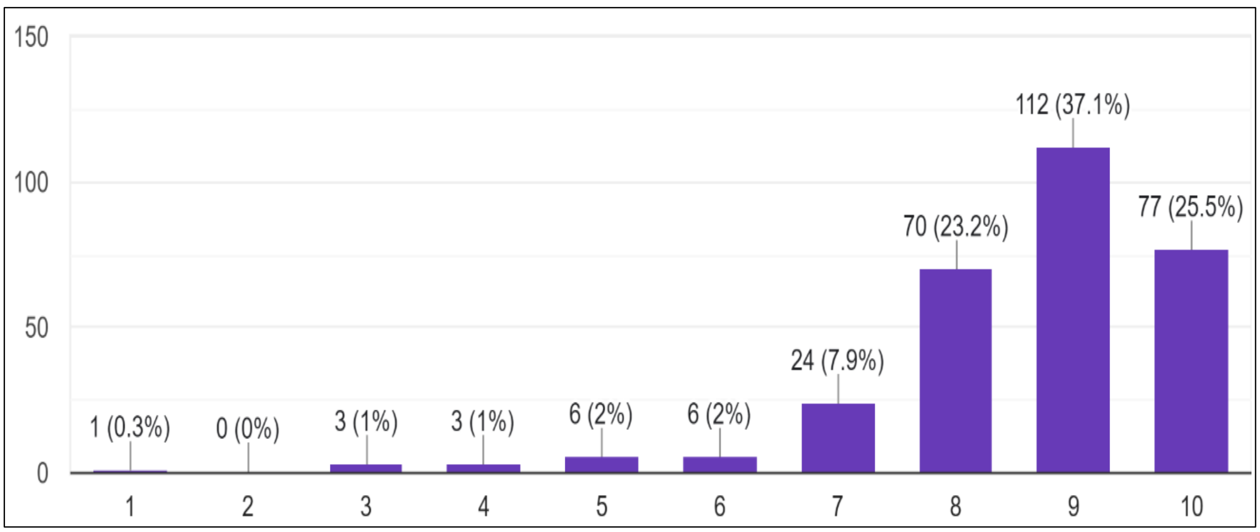
The comprehensive approach will boost social and economic development in India. Since comprehensive approach are integrating the intersectional filed. This will help to bring more economical solutions to do multifold development

# CHAPTER IV:
# RESULTS

### 4.1 Research Question One, what are the sources to integrated for sustainable future mobility in Indian context

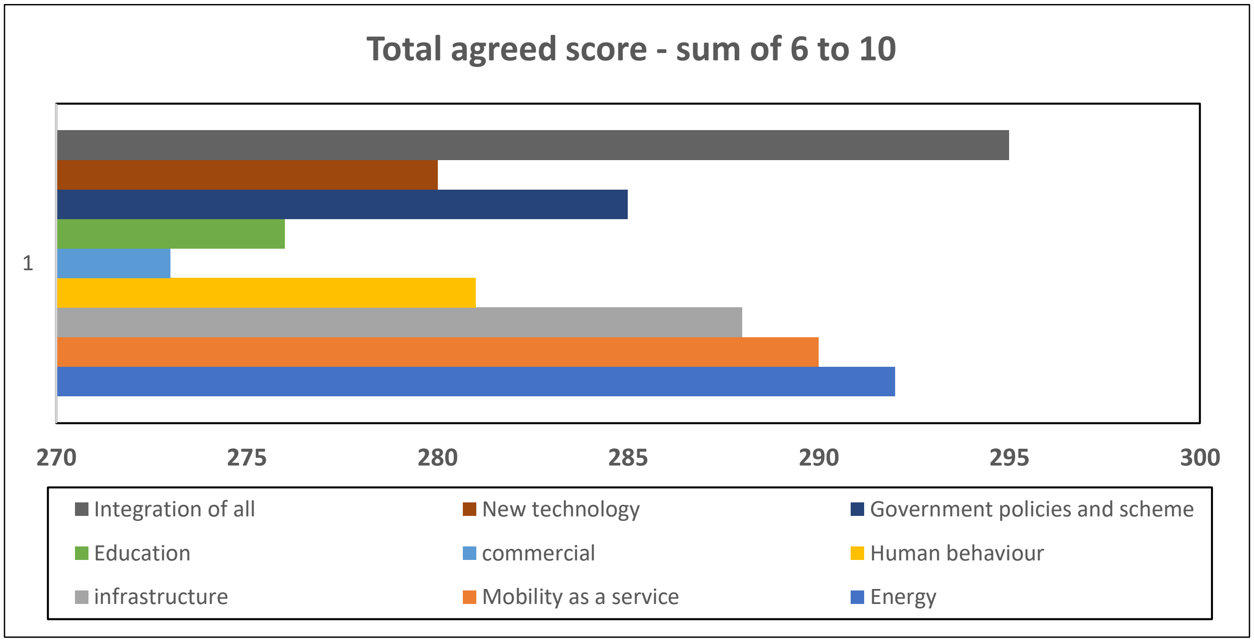
The research focused in area of the future mobility area majorly focus on decorbanisation of mobility. The greenhouse emission gas reduction has attracted major focus in sustainability aspects. But the research focused on the future mobility sustainability and faster mobility solution introduction has felt the need of the comprehensive for sustainable future mobility. At present the research on integrated approach for future mobility is missing. The studies and other research have understood the integrated approach the is required. But the detail research in this area is missing.

**Figure 4.1 sources integration for sustainable future mobility**




The purpose research study here is to identified sector which to integrate for sustainable mobility. The sectors and resource are selected consider the future mobility sustainability. The sum of all agreed feedback has taken to analyze responses.

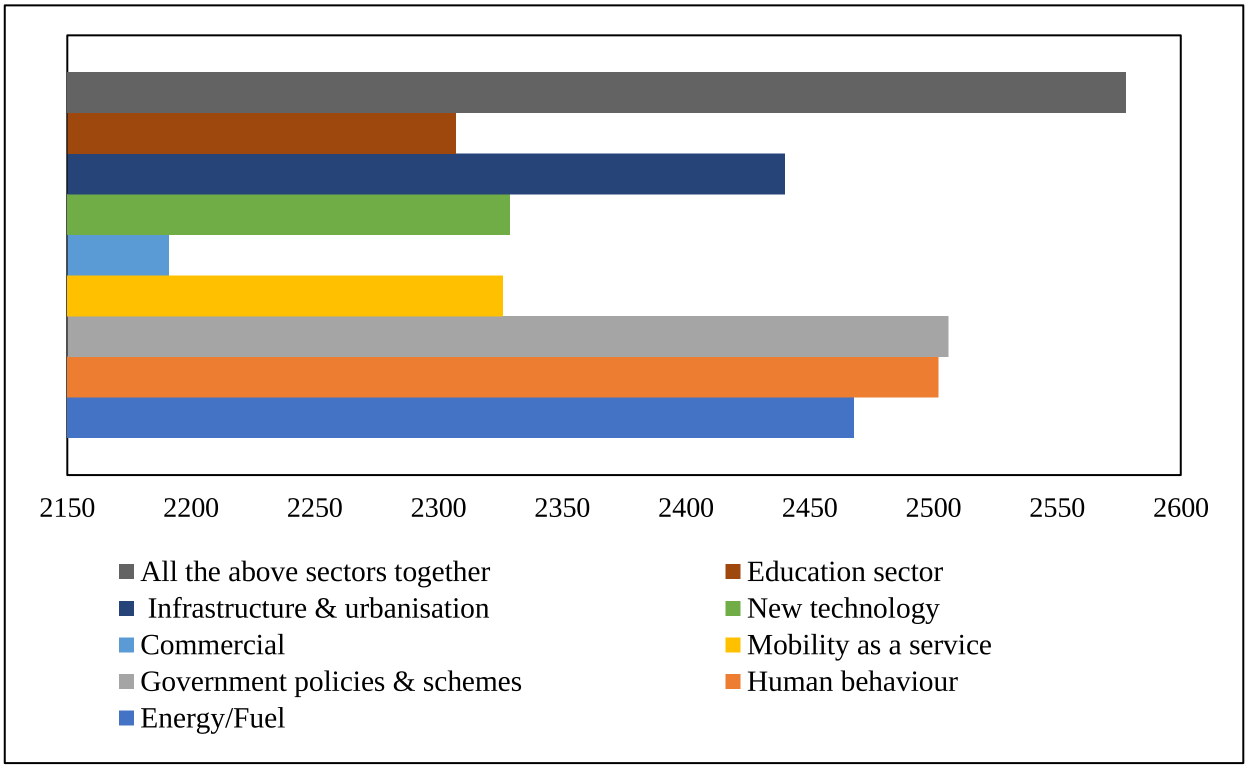
**Figure 4.2 Participant response on sources integration for sustainable future mobility**




The sectors other than mentioned here may require integration for sustainable future mobility. As per past research the integration of energy, human behavior, government policies and scheme, MaaS (mobility as a service), Commercial, new technology, infrastructure and urban development has been studied. The individual resource has own importance for self-integration. Since each have sub important elements and self-integrated themselves. The past research has studied self-integration of each sector and found results. But the self-integration has limitation toward sustainable future mobility.

The total agreeing scale 6 to 10 shows the integration of all sectors is at top for sustainable future mobility. As individual results of each sector contribution show that the energy sector is on of the top contributing sector. The mobility as a service is also one of the important contributing sectors after energy sector. The infrastructure is 3rd individual sector contributing for sustainable future mobility. Here, the infrastructures are majorly referred by participants is mobility infrastructure like electrical vehicle charging infrastructure, hydrogen fueling infrastructure, the technology infrastructure of the vehicles.

**Figure 4.3 sector wise resultant response for sustainable future mobility**




The individual research in energy sector, human behavior, infrastructure, commercial sector, government policies and scheme, technologies (digitalization, artificial intelligence) mobility as a service, education sectors have found own benefits. But the benefit toward sustainable future mobility is very limited. So, research for integration of sources is required to achieve the sustainable future mobility.

The integration of this source is not standard across all solutions. The intersection of this source for each mobility solution is different. The future mobility like electrical vehicle required integration of the alternate fuel powertrain technologies, energy sector, infrastructure, government policies and schemes, human behavior and education. So right chose of the source for integration for each solution. So, for sustainable future mobility need to decide sequence of source integration at planning stage with defined timeline is required.

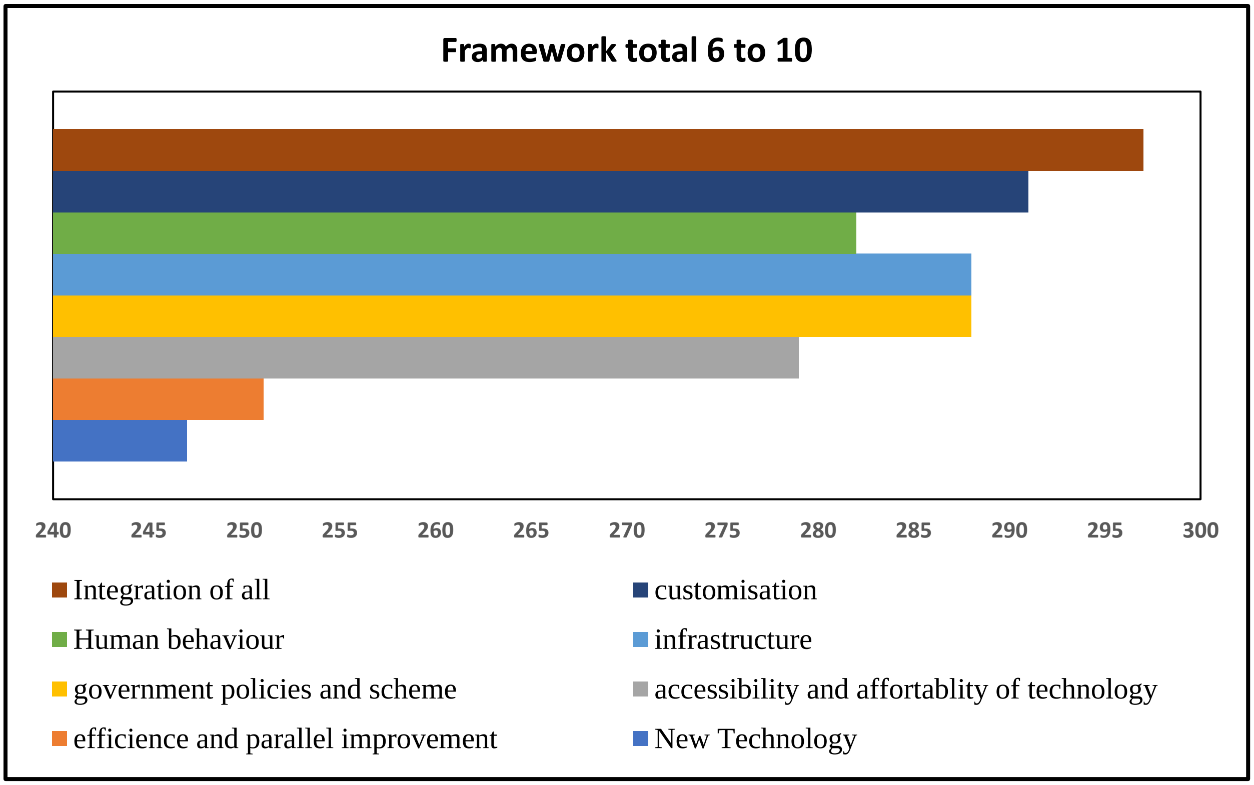
The integration of this sources is required. Since concentration on one source will help to achieve selected mobility goal. The sustainable future mobility scope required the end-to-end consideration of each source. As example, the alternate fuel powertrain technology like battery electrical vehicle, hybrid electrical vehicle or fuel cell technology required end to end sustainable evaluate for sustainability scope. The sustainability scope is included environmentally friendly, safer, accessible, affordable, reliable, efficient and socially desirable. The battery electric vehicle at present getting evaluated for the life cycle assessment of greenhouse gas emission or well to wheel greenhouse gas emission. The research has concluded that integration of the sources to achieve scope of the sustainable future mobility.

### 4.2 Economic framework to integrate technology, energy/fuel, government, infrastructure and consumers in Indian context

The sustainable future mobile is required integrated approach. In this the comprehensive economic framework to integrate technology, government, infrastructure and consumers is required. The past research is majorly focused on the megatrend technologies like electrical vehicle, connected car and MaaS (mobility as a service). There is no comprehensive research on economic framework for sustainable future mobility in Indian context. The elements like technology, energy/fuel, government policies, infrastructure and consumer are found common elements in future element studies. So, the purpose of this research to studies economic framework for sustainable mobilities. elements studies There are studies done on the challenges to implement the future mobility like electrical vehicle in India. As per research point has been note and this has given direction for economic framework.

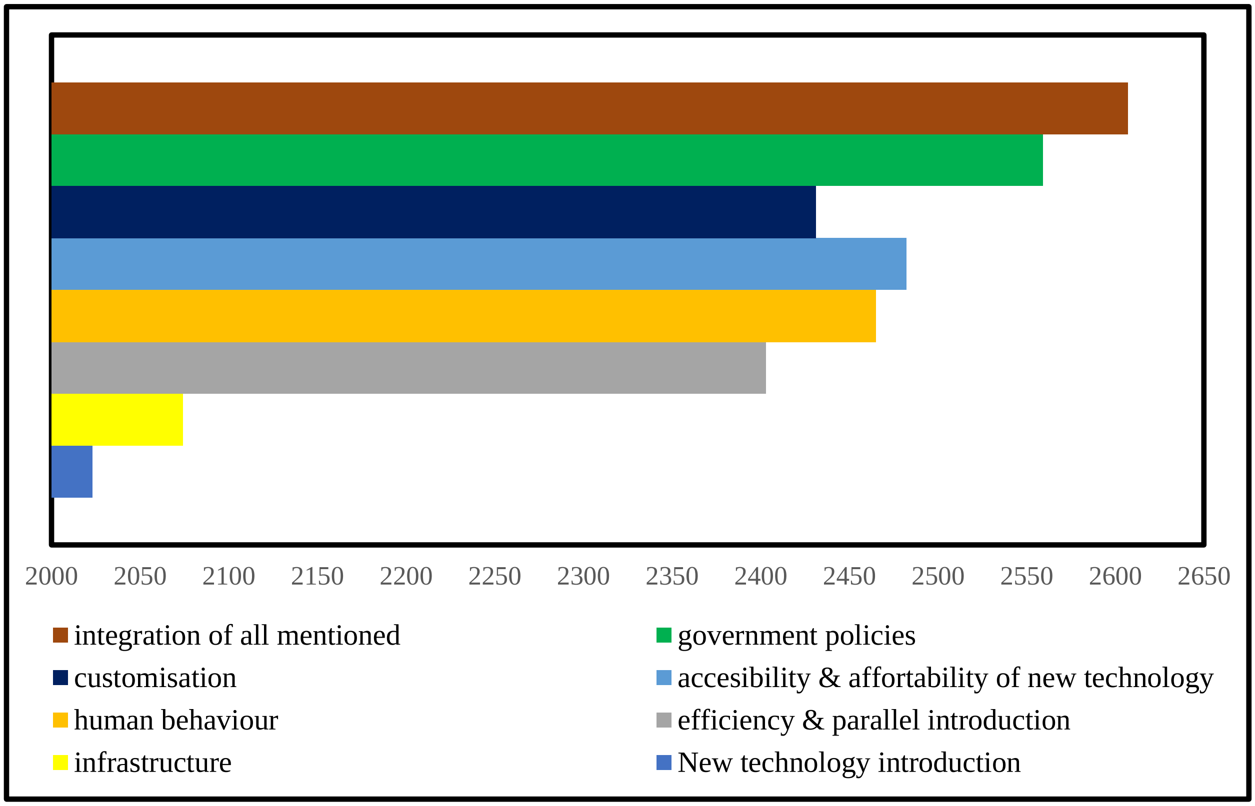
At present consumer referring future mobility for major mobility megatrend. The one of the future mobility trends discussed is electrical vehicle. The consumers are agreed that sustainable future mobility the faster introduction and implementation of new technology like clean energy, battery electrical vehicle and hydrogen vehicle is required. The consumer aligned for decorbanisation initiatives and greenhouse gas emission reduction. But equally concerned about the sustainability achievement with current and projected solutions. The electrical and hydrogen electrical vehicle point of view the consumers are concern about the charging infrastructure and battery technology over all sustainability. The consumers are aware about future mobility solutions and megatrend like electrical vehicle (include hydrogen and battery). The consumers are agreed that faster introduction and implementation of the future mobility solution required for the sustainable future mobility. In Indian context for sustainable future mobility efficiency improvement in current technology and phase wise parallel introduction of technology is required.

**Figure 4.4 sector wise framework for sustainable future mobility**




In past research in studies has been done on the cost of living, total cost of ownership, quality of life with future mobility. But in Indian context the compressive study not done. At present the cost of new future technology is higher. Since the cost of future mobility solution like electrical vehicle (battery electrical vehicle, hydrogen fuel cell) are higher compared to current mobility solution. The consumers are finding the higher initial investment in future mobility solutions. The total cost of ownership is one of the important parameters for current mobility in Indian context. For sustainable future mobility consumers are not completely convivence on the lower total cost of ownership. Since technology is not matured to validate the total cost of ownership.

**Figure 4.5 in India context resultant framework for sustainable future mobility**




The consumers are agreeing that sustainable future will help to boost the social and economic development in India context. So, integrating the energy/ fuel sustainability will help to bring sustainability. This framework will help to illustrate sustainable benefit due to future mobility

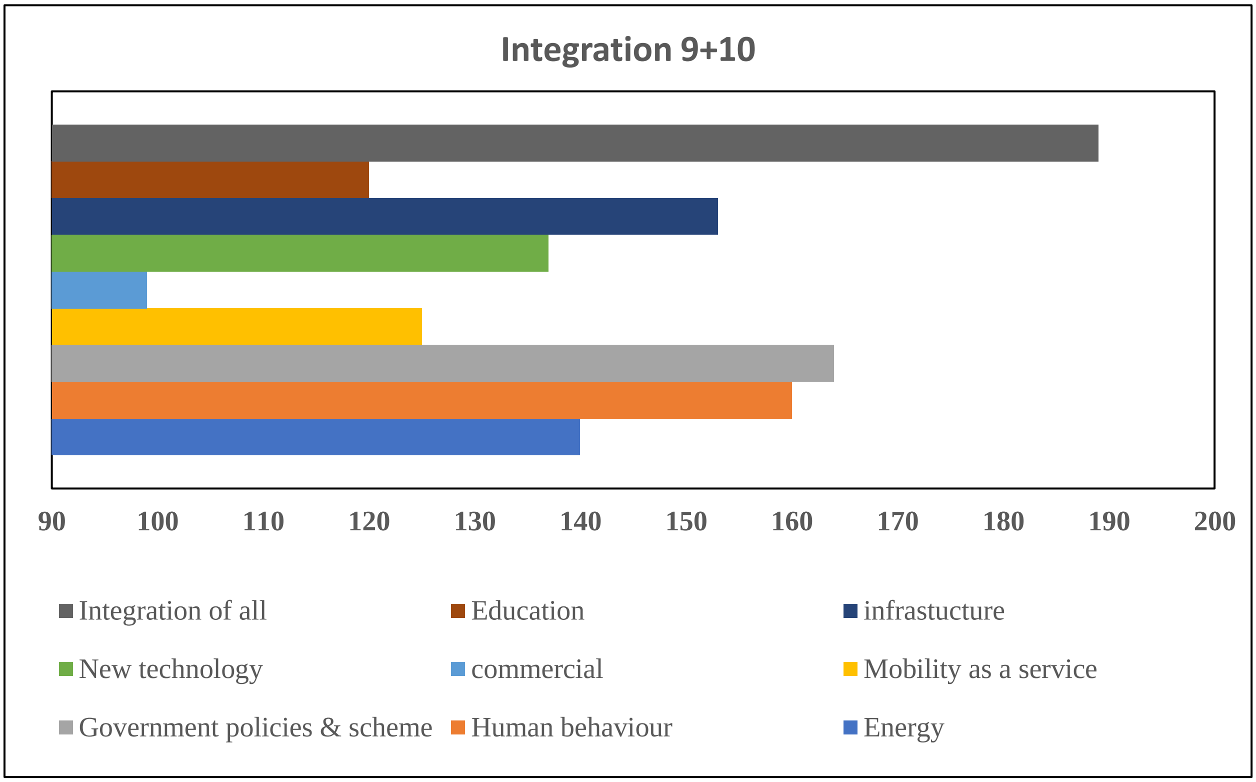
- The consumer is concern about the sustainability of current solutions. Like the battery electrical vehicle will help for greenhouse gas reduction but overall emission from battery manufacturing to the recycling.
- Aware about future technology but the current future technology solutions not economical at present. So, concern about increasing cost of living and total cost of ownership after implementation of the future mobility

- focus on human behavior in consumer point of view for adaptability of solution with lower cost of living and lower total cost of ownership
- customization the mobility solution to reduce the cost and increase accessibility of the solution
- future mobility technology implementations in phase wise manner and adding current mobility technology in flow of the future technology to evaluate affordability of mobility
- The mobility sector is investment intensive sector and strongly regulated by government regulation. So, integrated focus of government policies is required. The government clarity on the short term, medium term and long-term policies will help for sustainable mobility introduction

### 4.3 Conclusion

There is need to focus beyond the greenhouse gas emission in the area future mobility. The past research in India context is majorly focus on the greenhouse gas reduction to align with climate change goal. So, there was need to investigate wider scope of the mobility. As per research sustainable future mobile scope need to include environmentally friendly, safer, accessible, affordable, reliable, efficient and socially desirable.

**Figure 4.6 in India context integration for sustainable future mobility**



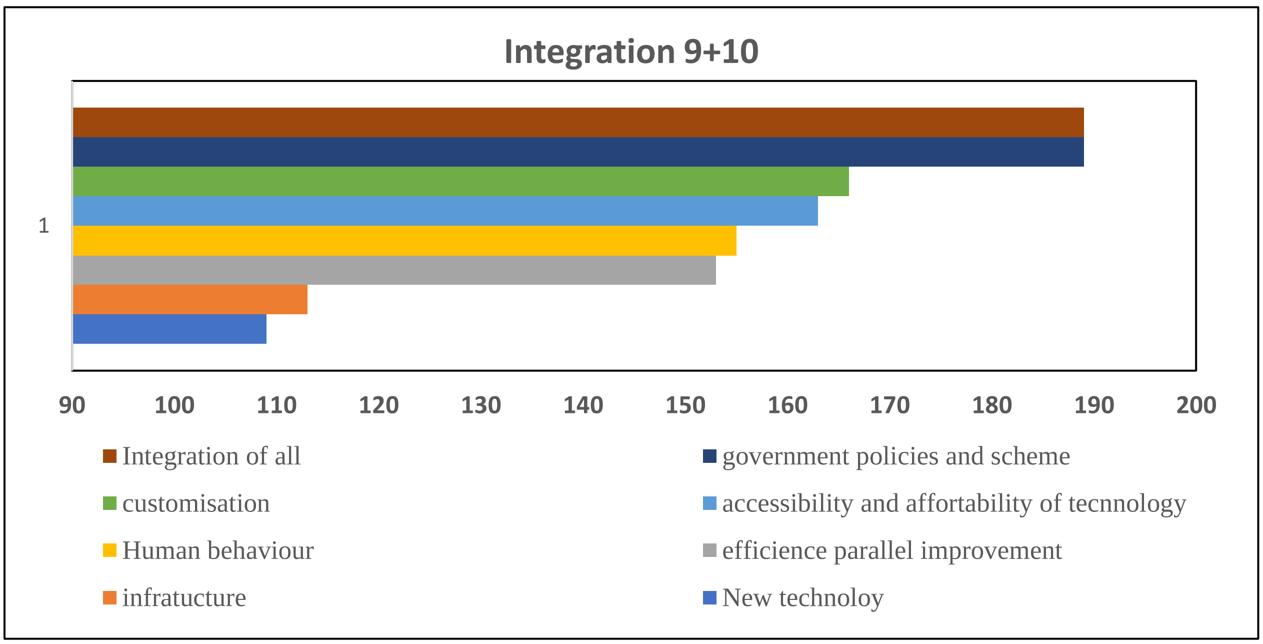

The scale 9 + 10 are strongly agreeing. The total of scale 9 + 10 is showing each element strong ageing contribution. The total scale of 9 + 10 showing integration of all sector contribution is important for sustainable future mobility in Indian context. In this as individual government policies are important after integration of all. This scope is giving confidence to develop the sustainable solution in are of future mobility. The respective region or country required different scope for sustainable future mobility.

**Table 4.1Sectror integration index for sustainable future mobility**

| | Total | Index | 9+10 score |
|---|---|---|---|
| 1 | Integration | Integration | Integration |
| 2 | energy | govt | govt |
| 3 | human | human | human |
| 4 | govt. | energy | infra |
| 5 | infra | infra | energy |
| 6 | MaaS | Mass | new tech |
| 7 | Educa | New tech | Mass |
| 8 | new tech | Education | education |
| 9 | commercial | commercial | commercial |

The sustainable future mobility scope required the integration of the sources. The comprehensive integration of energy sector, human behavior, infrastructure, commercial sector, government policies and scheme, technologies (digitalization, artificial intelligence) mobility as a service, education sources is required.

**Figure 4.7 in India context integration top sector for sustainable future mobility**




In the Indian context the economic framework required for sustainable future development. Since consumers are concern about the cost of living, total cost of ownership. The focus on this economic framework will help to increase accessibility and affordability of the future mobility to create sustainable future mobility. In this framework the customize solution for metro, urban, rural and connection between this will help for faster implementation of the sustainable mobility solution.

**Table 4.2 In Indian context top sector integration index for sustainable future mobility**

| index | total | 9+10 |
|---|---|---|
| Integration | Integration | Integration |
| policies | policies | policies |
| access and affordability | access and affordability | customisation |
| human | human | accessibility |
| customisation | customisation | human |
| efficiency | efficiency | efficiency |
| infra | infra | infra for battery |
| faster tech Intro | faster tech Intro | faster intro of new tech |

The comprehensive integration of sources and economic framework will help to boost Indians social and economic growth.

# CHAPTER V:

# DISCUSSION

## 5.1 Discussion on results

The research indicated new scope is required for sustainable future mobility. A sustainable future of mobility can be achieved with new scope by comprehensive integration of the intersection of sectors. Sustainable mobility will help to improve the quality of life and help to achieve climate change goals. This research has indicated the potential sources to be integrated for sustainable future mobility. Sustainable future mobility will help to integrate interaction of sectors sources and this will help for faster implementation of future mobility to address climate change goals. In the Indian context, an economic framework is required for sustainable mobility. The economic framework requires integration of technology, energy/fuel, infrastructure and government policies.

As per research review, the ongoing and projected future mobility efforts are focused on the decorbanisation of mobility to achieve mobility. The basis for ongoing decorbanisation of future mobility is to achieve climate change goals. Past research found that independent future mobility will not help to bring sustainability. The defining sustainable future mobility scope will help to faster implementation of future mobility.

As per past research in the field of mobility, it is independent of motor mobility in the center. The past research in India felt the need for integration for sustainable mobility. But at that time, it was not clear regarding what is to be integrated, where to integrate and which sector to be integrated. This research has cleared the integration requirement, source to integrate and benefits of the integration for sustainable future mobility.

As research understood, the integration of the sectors for sustainable future mobility is an emerging field in the context of India.

### 5.2 Discussion on research question one

This research has addressed the point of which source to be integrated for sustainable mobility. This is one of the important research results to give direction for further research in the field of sustainable future mobility. These sources are studied in the context of India. The purpose of research to provide a comprehensive report to integrate sectors. As per research, integration of sources will help for sustainable future mobility.

In India, major research was done in 2020 and found that the ongoing efforts will not help with sustainable mobility without integrated mobility. At the time, it was unclear what sources to be integrated for sustainable mobility. Sustainable future mobility requires integration of sources and within the sources.

India is looking toward electrical mobility as the future mobility and electricity are required for that. Electricity is produced in India from carbon intensive resource. So, even with electrical mobility, the decorbanisation level will not be reduced. So, the integration within electricity sources and integration of that with electrical with right infrastructure is necessary. At present there is concern about electrical vehicle battery sustainability and which need to be addressed by source integration.

### 5.3 Discussion on the research question two

The purpose here is to provide a comprehensive economic framework. For a comprehensive economic framework, integrate technology, fuel/energy, government and infrastructure. The integration of this is done by changing human behaviors to increase adaptability and affordability for faster implementation of sustainable future mobility in India. In India at present there is no detailed economic framework for sustainable future mobility.

The economic framework is important as per the cost of living, total cost of ownership and affordability. This will help to bring a behavioral change towards sustainable future mobility. The narrative of the decorbanisation of mobility is not convincing to the majority of consumers.  Since decarbonize future mobility is not affordable and looking for reduction in the total cost of ownership in India.

As per past research studies, in the field of future mobility there are commercial challenges.

The developed countries and developing countries have some uncommon challenges. So, the framework provided here includes changing human behavior towards sustainable future mobility, reduce cost of living, reduce total cost of ownership. So, there is social and economic development of the countries. Here, integration of government policies and schemes with government and integrated sources is important. At present there are individual policies and schemes there. But this is not helpful for the economic framework here in India.

A national level of sustainable future mobility can be created by integrating education source. This will help to model and simulate the integration of each source technically, socially and economically. This kind of integrated initiative will help to give further direction and economic for research. The economic framework for sustainable future mobility is required in the Indian context to address the cost of living and total cost of ownership concern. The economic framework will help to integrate human behavior into sustainable future mobility. These will help to boost multifold social and economic development in India.

### 5.4 Discussion on the research question three

At present India have highest import dependent country for crude to make fuel for mobility. In 2022 India crude dependency was 85.3% and spend USD 121 billion in volume 210 metric ton. In India there are continuous efforts to reduce greenhouse emission and meet vehicle level emission target in line with global emission target. The vehicle level emissions are controlled by strong policy and measures on place. At present there is dominance of fossil fuel mobility in India. So, the emission reduction controls are strong on this. Along with current mobility present India is embracing future mobility and adding efforts to future trends. There is focused to decarbonise current mobility and developing the alternate fuel. The government of India’s alternative fuel initiatives are as below.

1. FAME (Faster adoption and manufacturing of hybrid and electrical vehicle)
2. Biofuel 150 crore liters by 2025
3. Hydrogen mission Rs. 8 lakh crores (green hydrogen 5million tone/annual)

The electrical vehicle adoption among future mobility megatrends is taking traction on India. For electrical vehicle adoption the government has released policies and initiative taken. The FAME (faster adoption and manufacturing of hybrid and electrical vehicle), PLI (production link incentives) and incentives for battery cell manufacturing are implemented considering electrical vehicle. The emission of electrical vehicle is less compared to the fossil fuel vehicle and comparison happening based on tail pipe emission. But electrical vehicle emission is far beyond the tailpipe emission. The emission in electrical major by well to wheel to capture total emission thought out entire cycle of the. The electrical energy sources are carbon intensive in India. So, the emission reduction due to electrical vehicle is not significant with this. But energy produced with renewable energy will help to reduce emission reduction significantly.

At preset India is trying to catch the global megatrends like MaaS (mobility as a service) but the important of this is not yet completely quantifiable in terms of emission reduction. The MaaS (mobility as a service) is getting popular in India. But still there is person vehicle ownership have importance and social value. The connected vehicle and autonomous vehicle are at nascent stage of develop compared to developed mobility market.

### 5.5 Discussion on the research question four

The mobility is one the important for everyone's in everyday life. The per capita income in India is low compared to developed countries. But this is increasing with economic development in India. The awareness about quality of life is increasing. The quality of life is coming in focus area and day by day importance is gaining. The quality of life is not only about reduction in emission reduction to reduce the disease and fatality. But it's about well-being development. At present in India road, congestion, slow moving traffic, road accidents, high cost of comfortable technology mobility, affordability and accessibility are challenges. The sustainable future mobility considering the sustainability as per with involvement of environment, economy and ecology. The challenges mentioned here are not limited to individual sectors. The quality of life is about wellbeing and not related to only emission reduction. The quality of life has perceived understanding. But there is standard global definition available for this to quantify. So, by only concentrating on emission reduction of motorised vehicle need to work on sustainable future mobility.

The quality of life aspect is getting traction due to increase in health awareness and help to bring sustainability aspect in man flow of discussion. There is strong believe in sustainable future mobility to improve quality of life. As per latest global finding sustainability come with some premium cost. So sustainable future mobility as per will help to achieve long term and committed goal of $ 5 – 7 trillion in 2023. The sustainable future mobility has strong influence on the quality of the life.

### 5.6 Discussion on the research question five

At present the consumers are not convenience with current future mobility projection. But bring sustainability by future mobility develop will help to give confidence to consumers. So, consumer will convince to embrace the future mobility. So even there is premium to pay for mobility with respect to current mobility consumer will be ready to pay. The present analysis of the future mobility solutions indicated that affordability is high with respect to present mobility. As per sustainable future mobility the new features and specification are required and this not commercial viables. But the scaling up of production and mass adoption of solutions will help to reduce cost.

The cost of life is one of the important elements in India. At present the per 1000 per vehicle count is approximately 75including 2 wheel and 3. So the total 4-wheel mobility are less. This is ratio less compared to developed nation. The major reason for this is the cost of life. But once as per sustainable future mobility approach increase in affordability will help for faster penetration.

The cost of life is one of the important elements to address in sustainable future mobility. But sustainable future mobility aspect will help to address this point in wholistic way.

# CHAPTER VI:

# SUMMARY, IMPLICATIONS AND RECOMMENDATIONS

## 6.1 Summary

The purpose of the study is to provide comprehensive research to integrate respective sectors for sustainable future mobility. The research has concluded that integration of the energy sector, human behavior, infrastructure, the commercial sector, government policies and schemes, technologies (digitalization, artificial intelligence) mobility as a service and the education sector are required for sustainable future mobility. The integration of the sectors will help for sustainable future mobility. In past research there was no clear idea which sector to be integrated for sustainable future mobility. The economic framework to integrate technology, energy/fuel, government, infrastructure and consumers has been established. This will help to boost the social and economic development in India.

In India the multi-disciplinary mission has kick off. This mission has included the on transformative mobility and electrical battery storage. This mission is chaired by the NITI Aayog CEO and involve inter-ministerial steering committee. The steering committee compromise secretaries from the ministry of road transport and highway, the ministry of power, the ministry of new and renewable energy department, department of science and technology, department for promotion for Industry and internal trade and director general before bureau of Indian standard. The purpose of mission to drives the strategies and recommendation to transform the mobility technology and manufacturing of electrical vehicle and battery components. In this mission the phased wise manufacturing program for electrical vehicles and entire EV value chain for localization of production. The national mission on transformative mobility and battery storage will determined the contours of and finalized by mission with clear make in India strategy for electrical vehicle compound as well as a battery. In this mission objective is to integrate various initiatives to transform mobility in India with coordination of the key ministries department key stakeholders.

At presents partners are included commercial institutions, FICCandI, ACMA, ARAI and IITs, shakti foundation, WRI. The government level data and study done (report of NITI Aayog).

- Leap ahead Transformative mobility solution
- Valuing society 1st – an assessment of the potential for feedable policy in India
- India Energy storage mission to a make opportunity for globally battery manufacturing
- Transforming India's mobility: towards a policy perspective
- Zero emission vehicle toward policy framework
- Efficiency and sustainability in goods move
- Data drive mobility

## 6.2 Implication

The research focusses on a sustainable future of mobility. In this research, this sustainable future mobility is considered beyond the decorbanisation to bridge the public trust gap and accelerate its implementation. The alternate fuel motorized vehicle is central in future mobility research in most cases. This research is not specific to the motorized vehicle but guidelines for which sector to integrate to address the sustainability in future mobility from the start of evaluation. The past research is either stated as future mobility, sustainable mobility, or the future of sustainable mobility or decarbonization of mobility. But there is limited research to sustainable future mobility. The major focus in past research is to decarbonize the mobility sector to achieve the climate change goal. The various research data available on this. This research finding will provide the basis for future research to integrate the intersection sector to achieve sustainability in future mobility. At present, in India, this kind of research is not yet done.

At present, in India, the cost of mobility is not economical due to higher technology costs, high cost for technology affordability and minimum accessibility of the technology. Through this research, an economic framework has been developed. Due to this cost of living, the total cost of technology and human behavior towards adaption of future mobility will increase. This kind of research is not conducted in an Indian context. There are numerous future mobility solutions evolving. So, in future, the integration sector may change based on the type and region of mobility.

### 6.3 Recommendation for future research

This research is focused on defining the integration of the sector for sustainable future mobility. The sustainable future of mobility is a vast field. So below a recommendation for conducting future research. In future research, interaction effects of the intersection sector can be studied. This will help to study the interaction effect and effectiveness of interaction for sustainable mobility implementation. The sector integration study can be done for different regions and counties. In future research, economic framework study can be done with different elements of models that can be prepared. So, economic framework modelling can be done for different parameters for different regions. The same sector integration and the economic framework integration study can be done for respective regions. Which will help to identify the framework for faster implementation of future mobility.

India has the world largest fleet of 2 and 3-wheeler its transition to electrical vehicle is about $ 285 Billion financial market. Electrical 2 and 3-wheeler fleet provide low cost and zero emission mobility to people and goods in our cities. The government of India focusing on the Innovative flagship scheme to scale up electrical mobility in the country two and three-wheeler account for 80% of vehicle scale in India.

FAME – faster adoption and manufacturing of electrical vehicle. At present 45 certified electrical vehicle manufacturer cumulative scale reach 1 million out of India total fleet stock 250 million.

### 6.4 Conclusion

The proposed research is to define integration of sectors required for sustainable future mobility. This research will help to integrate the sector which is required for sustainability of future mobility. This will help to consider the sector proactively. At present there is a focus on developing the future technology which helps for decorbanisation of mobility. But this research will help to focus on scope as well, which is required for sustainable future mobility. This research will help to give economic framework thought for faster implementation of sustainable future mobility.

Affordable, accessible, inclusive and safer mobility solutions are primary strategic levers for rapid economic development as well as for improving 'ease of living', share, connected ns clean mobility solutions are increasingly becoming key principles off effective mobility solutions across the world. Given its commitment to climate goals, India needs to adapt effective strategies to place itself as a key driver of the mobility revolution in the world. Hence there was nee to felt to establish a dedicated multidisciplinary mission that will facilities co-operative federalism, extensive stake holder and inter-ministerial consultation as well as implement an end-to-end policy framework for transforming the mobility landscapes with particular focus on

- Manufacturing
- Specification and standards
- Fiscal incentives
- Overall demand creation and projections
- Regulatory framework
- Research and development

This initiative will pay significant dividend to rapidly urbanizing India in the decade to come. This will help to attract the consumer and help to boost social and economic growth in India.

# APPENDIX A

## RESEARCH SURVEY COVER LETTER

Dear Friend,

Reserch Title - “Sustainable Future Mobility”

Reserch guide/mentor – Dr. Edurd Plavec PhD ( SSBM Geneva Switzrlant )

I am Devendra R Gandhi, Doctorate (DBA) scholar and a techno commercial executive working in “Mahindra and Mahindra Limited. I am doing research in the field of “Future Mobility” and various perspectives around it. One of the important perspectives among all this is “sustainability” and not yet addressed in detail.

“Sustainable Future Mobility” refers here as an “affordable, accessible, safe, efficient, safe and resilient, while minimising emissions and environmental impact”

The purpose of this research is to discuss a new way forward by this to provide services and infrastructure for the mobility of people and goods - advancing economic and social development to benefit todays and future generation.

So doing research on this and get your important feedback to take it forward. Please help to respond on below.

APPENDIX B

INFORMED CONSENT

I,…………………………………………agree to be interviewed for the research which will be conducted by Devendra Rajaram Gandhi, a doctorate student at Swiss School of Business and Management, Geneva, Switzerland. I certified that I have been told of the confidentiality of information collected for this research and anonymity of my participation; that I have been given satisfactory answers to my queries related to research procedure and other concern matters; and that I have been informed that I am free to withdraw my consent or discontinue participation in the research or activity at any time without prejudice. I agree to participate in one or more electronically recorded interviews for this research. I understand that such interviews and related materials will be kept completely anonymous and that the results of this study may be published in any form that may serve its best. I agree that any information obtained from this research may be used in any way thought best for these studies.

………………………….                                                        ………………………

**Interviewee**                                                        **Date**

APPENDIX C

INTERVIEW GUIDE

{Sample Text Sample Text Sample Text Sample Text Sample Text Sample Text Sample Text }

REFERENCES

[1.], Andrei S., Sergey P., Henry C., Martin H, Ronald P, and Erwan M., c*limate stabilization at 2°C and net zero carbon emissions*, MIT, 2017, pp 1-16

[2.], Adam S., Charles F., Erwan D., Evan C., Henry J., Jeffrey S., Jennifer M., Martin M., Qudsia E., Ronald P., Sergey P., Andrei S., Stephanie D., Xiang G. and Chen Y., *modelling framework to assess multi sector climate impacts*, 2018, pp 1-5

[3.], Accenture, *Mobility as a Service, 2016*, 2017, pp 2-10

[4.], Arem B., Rieck F. and Boersma R., *application of driverless electric automated shuttles public transport in villages, appelscha*, 2018, pp. 1-7

[5.], Axsen J., Plotz P. and Wolinetz M., *integrated policy mix for deep carbon-di-oxide (CO2) mitigation in road transport*, IEA, 2020, pp 809-818.

[6.], Axsen J. and Wolinetz M, *30% plug in vehicle (PEV) sales by 2030, modelling of incentive and sales mandate in Canada,* transport research part-D: 65, 2018, pp- 596-617.

[7.], Axsen J., Crawford C., Peters J. and Wolinetz M., s*imulating value of (EV) electric vehicle grid integration by behaviourally realistic model*, nature energy, 2018, pp -132-139.

[8.], Ambrose H., Fulton L., Kendall., Lozano M. and Wachche S., *life cycle (GHG) greenhouse gas emissions of future light duty (EV) electric vehicles*, transport research part-D:81, 102287, 2020.

[9.], Axsen J., Crawford C. and Kamiya G., *modelling GHG emissions intensity of (PEV) plug-in electric vehicles with short term and long-term perspectives*, transport research Part D: 69, 2019, pp-209-223,

[10.], Axsen J., Hammond W. and Kjeang E., *slash greenhouse gas emissions (GHG) in the freight sector: Policy insights technology adoption model Canada*, energy policy-137, 2020

[11.], Axsen J., Crawford C. and Lajevardi S., c*omparison alternative heavy-duty drivetrains GHG emissions, ownership and abatement costs, Simulations in British Columbia,* transportation research Part D - 76, 2019, pp 19-55.

[12.], Axsen J., Melton N. and Moawad B., w*hich plug-in electric vehicle policies are best, a multi-criteria evaluation framework applied to Canada*, Energy Research and Social Science 64, 10141, 2020

[13.], Ayetor A., Deyegbe R., Opoku G. and Sekyere K, *cost of a transition to electric vehicles in Africa: study of Ghana*, Transport Policy, 2021

[14.], Axsen J., Crawford C., Peters J. and Wolinetz M., *value of (EV) electric vehicle grid integration using a behaviourally realistic model*, nature energy 3, 2018, pp- 132-139,

[15.], Axsen J. and Lepitzki J., *role of a low carbon fuel standard in achieving long-term greenhouse gas (GHG) reduction targets,* energy policy - 119, 2018

[16.], Ahluwalia K., Borup L., Cullen A., Kusoglu A., Mukundan R., More L., Myers J., Neyerlin C. and Weber Z., n*ew roads and challenges for fuel cells (FCEV) in heavy-duty transportation*, nature energy - 6, 202, pp 462-474,

[17.], Axsen J., Long Z. and Kitt S., *vehicle emissions, low-carbon fuels and zero emission vehicle (ZEV) sales standards in Canada and California:* transportation research part A, policy and Practice 141, 2020, pp -98-115

[18.], Axsen J., Jaccard M. and Rhodes E., *exploring citizen support different types of climate policy,* ecological economics-137, 56-69, 2017

[19.], Acheampong A. and Siiba A., *Modelling the determinants of car-sharing adoption intentions among young adults: the role of attitude perceived benefits travel expectations and socio-demographic factors,* Transportation 47, 2557-2580., 2020

[20.], Azar C. and Sanden A., e*nvironmental innovation and societal transitions, the elusive for technology neutral policies,* 1, 2011, pp - 135-139.

[21.], Auffhammer M., Shaffer B and Samaras C., *make electric vehicles lighter to maximize climate and safety benefits.* Nature 598, 2021, pp- 254-256.

[22.], Ardic O., Annema A., Molin E. and Wee B.*, the association between news and attitudes towards a Dutch road pricing proposal*, *transportation* 45, 2018, pp- 827-848.

[23.], Axsen J., Jaccard. and Rhodes E., c*itizen support for climate Policy*, ecological economics 2017, pp- 56-69.

[24.], Axsen J., Plotz P. and Wolinetz M., *integrated policy mix for deep CO2 mitigation in road transport*, climate change -10, 2020, pp - 809-818.

[25.], Axsen J. and Sykes M., *simulating own zero-emissions vehicle (ZEV) mandate to achieve 2050 GHG targets*: *no free ride to ZE:* Energy Policy-110, 2017, pp- 447-460.

[26.], Axsen J., Melton N. and Moawad B., w*hich plug-in electric vehicle policies are best, Multi-criteria evaluation framework applied to Canada. Energy Research and Social Science* 64, 101411, 2020

[27.], Axsen J., Goldberg S., Kormos C. and Long Z., *latent demand for zero-emissions vehicles (ZEV)in Canada*, transport research part D: 67, 2019, pp -685-702.

[28.], Axsen J., Goldberg S. and Melton N., e*valuating plug-in electric vehicle (PEV) policies for long-term greenhouse gas reduction (GHG) goals: 10 Canadian provinces,* energy policy 107, 2017, pp- 381-393.

[29.], Axsen J., Miele A., Maine E. and Long Z. and Wolinetz M., *role of charging and refuelling infrastructure on zero-emission vehicle sales, transportation research D 81*, 102275, 2020

[30.], Axsen J., Melton N. and Sperling D., *moving beyond alternative fuel hype to decarbonize transportation*, Nature Energy 1, 2016, pp-1-10.

[31.], Axsen J., Bhardwaj C., Kern F. and McCollum D., *Why have multiple climate policies for light-duty vehicles? Policy mix rationales, interactions and research gaps, Transportation* Research Part A: Policy and Practice 135, 309-326, 2022

[32.], *Association for European Transport: Henley-in-Arden*, UK, 2017.

[33.], Alcantara S., Bachinge M., Parodi O., Kuhn R., Soylu M., Rhodius R. and Waitz C., *insights and recommendations from 3 real-world laboratories,* 2018, pp- 52–59

[34], Arlanch S., *Citizens' council, models in the perspective of community work and governance*, Association for the Promotion of Socio-Political Work (PSPW), 2011.

[35.], *BloombergNEF, Electrical Outlook 2022 Vehicle special*, 2022, pp 1-5

[36.], Bruno S., Bruna M., Ferreira C., Oliveira A., Sampaio R. and Rodrigo C., *adding technology sustainability evaluation to product development: a proposed methodology an assessment model*, 2021, pp 1-22

[37.] Brundtland R., *World Commission on Environment and Development* (WCED), 1987

[38.], Bentley C., Clinton R., Knittel C., Elgar E., Glachant J, Metaxoglou K, Northampton A and Joskow P., *Electrifying Transportation: Challenges and Opportunities*, 2019 pp 3-50

[39.], Banister D., Erling H. and Gilpin G., *Sustainable Mobility at Thirty*, MDPI, 2019

[40.], Berckmans G., Messagie M., Smekens J., Omar N., Vanhaverbeke L. and Mierlo J., *Cost projection of state of the Art lithium Ion (LiI) batteries for (EV) electric vehicles up to* 2030,2017, pp 314–1334,

[41.], Bock S., Boysen N., Briskorn D. and Schwerdfeger S., *Optimizing the electrification of roads with charge-while-drive technology*, European Journal of Operational Research, 2021

[42.], Booto K., Aamodt E. and Hancke R., *comparative (LCA) life cycle assessment of heavy-duty drivetrains, a Norwegian case,* transportation research Part D - 95, 2021

[43.], Bernstein S., Hoffmann M., Lemphers N. and Wolfe A., *regional innovation assets and the politics of electric vehicle leadership in, Norway, California and Québec*, energy research and social science-87, 2022

[44.], Bataille C. and Li F., *Emerging climate technologies in the energy supply sector*, Technology Executive Committee, UNFCCC, 2021

[45.], Bento A., Klotz R. and Landry R., *biofuel policies for critical importance leakage in land and fuel, carbon savings from Unites State (U.S.)* energy journal-36, 2015, pp-75-109

[46.], Boig A., Avila I., Brand C., Dons E., Gerike R., Gotschi T., Gascon M., Gaupp M., Iacorossi F., deNazelle A., Kahlmeier K., Panis L., Nieuwenhuijsen J., Racioppi F., Rueda R., Stigell E., Standaert A., Sulikova S. and Wegener S., *active travel climate change mitigation impacts, panel study in 7 European cities*, global environment change *67*, 2021

[47.], Boutueil V., Coulombel N., Liu L., Viguie V. and Yin B., *Urban ridesharing's substantial rebound effects: Simulating travel decisions in Paris, France*. Transportation Research Part D: Transport and Environment, 2019

[48.], Baptista P., Melo S. and Rolim C., *energy, environmental impact of mobility of car- sharing systems:* empirical results from Lisbon (Portugal), 2014, pp 28-37.

[49.], Bucher D., Buffat R., Froemelt A. and Raubal M., *Energy and greenhouse gas emission reduction potentials resulting from different commuter electric bicycle adoption scenarios in Switzerland,* Renewable and Sustainable Energy Reviews 114, 109298, 2019

[50.], Bian Z., Circella G., Liu H. and Wang C., *Assessing the role of shared mobility services in reducing travel related greenhouse gases (GHGs) emissions: focusing on America's young adults, travel behavior and society* 26, 301-311, 2022

[51.], Brakewood C., Cherry R., Cole J., Shah R., Wen Y. and Ziedan A., *complement or compete The effects of shared electric scooters on bus ridership,* Transportation Research Part D: Transport and Environment 101, 103098, 2021

[52.], Bigotte F., Hasselwander M., Antunes P. and Sigua G., *towards sustainable transport in developing countries: Preliminary findings on the demand for mobility-as-a-service (MaaS) in metro manila*, transportation research part A: policy and practice 155, 501-518, 2022

[53.], Bataille C., Guivarch C., Hallegatte S., and Waisman H., *Carbon prices across countries*, nature Climate Change 8, 2018, pp - 648-650.

[54.], Bergmann M., Bos J., Burch S., Davies A., Luederitz C., Schäpke N., Wiek A., Lang J., Evans J. and Konig A., *evaluative scheme for sustainability transition experiments. J. Clean production,* 2017 pp - 61–76

[55.], Beiker S., Maurer M., Gerdes C., Lenz B. and Winner H., *implementation of an automated mobility-on-demand system, in autonomous driving,* Springer: Heidelberg, Germany, 2016; pp. 277–295.

[56.], Bergmann M., Lang J., Schapke N., Brodowski S. and Stelzer F., *creating Space - real-world laboratories for sustainability transformations,* 2015, pp- 281–284.

[57.], Bulkeley H., Broto C, Evans J, Hodson M, Karvonen A. and Marvin S., *a living laboratory for sustainability: exploring the politics and epistemology of urban transition. in cities and Low Carbon Transitions;* London, UK, 2011; pp. 126–141

[58.], Beecroft R., a *process-oriented analysis of six transdisciplinary, sustainability (RWL),* 2018 pp - 10

[59.], Bakker P., Savelberg F. and Moorman S., *Conditions for Success in Public Transport Innovations, 47th ETC, Barcelona, Spain AFET,* Henley-in-Arden, UK, 2017.

[60.], Bergmann M., Jahn T., Knobloch T., Krohn W., Pohl C. and Schramm E., *Methods of transdisciplinary research, Germany,* 2010.

[61.], Bergmann M., Schäpke N., Stelzer F. and Lang D., *advancing transdisciplinary research and sustainability transformation:* 2018, pp- 8–11

[62.], Bradwell P. and Marr S., *an international survey of public Service Co-Design*, PwC's PSRC London, UK, 2008.

[63.], Bergold J. and Thomas S., *participatory research methods: a methodical approach in motion forum qual*. Soz., pp- 2012

[64.] Brost M., Chen T., Chen B., Chiu T., Deiber O., Fang E., Fraedrich M., Gong G., Hsiao M., Hsieh D., Klötzke M., Kopp G., Karnahl K., Lin H., Liu L., Lin C., Müller A. and Sippel T., *application of the living lab concept: Empirical validation in Taiwan's Minsheng community. Int. J. Autom.Smart Technol*, 2012

[65.], Chun J., Moody J. and Zhao J., *Transportation Policy making in Beijing and Shanghai,* 2019, pp 2-22

[66.], CleanTechnica, *Mobility edition,* 2021, P5

[67.], Chlebis P., Tvrdon M., Havel A. and Baresova K., s*tandard - fast charging methods for (EV) electric vehicles*, advances *in e and e engg.*, 2014 pp 111–116

[68.], Charles F., Adam C., David K., Erwan M., Evan C., Henry J., Jeffrey S., Jennifer M., Martin H., Qudsia E., Ronald P., Sergey P., Andrei S., Stephanie D., Xiang G. and Chen Y, *consistent modelling, framework to assess multi sectoral climate impacts*, 2018, pp 1-5

[69.], Clewlow R. and Mishra S., d*isruptive transportation – utilization, adoption and impacts of ride hailing in United States (US)*, Davis, California, 2017

[70.], Cervero R., Golub A. and Nee B., l*onger term travel demand car ownership impacts: city car share: transportation research*: transportation research board Journal, 2007, pp -70-80,

[71.], Cohen A. and Shaheen A., carsharing outlook: carsharing market, analysis and trends innovative mobility, university of California, Berkeley, 2020

[72.], Creutzig F. and Edenhofer O., McGlynn E. and Minx J., *evaluation of current framework, climate policies road transport*, energy policy -39, 2011

[73.], Cherry R., Bao J., Huo Y., Li X., Yang H. and Yang L., Impact of e-scooter sharing on bike sharing in Chicago. Transportation Research Part A: Policy and Practice 154, 2021, pp 23-36

[74.], Cavallaro F., Giaretta F. and Nocera S., *road pricing schemes for carbon emissions reduction*, transport policy - 67, 2018, pp -85-92.

[75.], Combet E., Edenhofer O., Hepburn C., Klenert D., Mattauch L., Rafaty R. and Stern N., *carbon pricing work for citizens*, nature climate change, 2018, pp - 669-677.

[76.], Chandan A., Hardman S., Tal G. and Turrentine T., effectiveness of purchase incentives in battery electric vehicles, renewable and sustainable energy-80, 2017, pp -1100-1111.

[77.], Christensen R., Levin L. and Uteng P., *Gendering Smart Mobilities; Routledge: Abingdon*, UK, 2020

[78.], Cornet Y and Gudmundsson, b*uilding a meta framework for sustainable transport indicator*, 2015, pp 103–112

[79], Cleaver F., *Questioning participatory approaches for development*, 1999

[80.], Dibbert B., Schneider J. and Krzyzanowski M., *Health effects of transport - related air* *pollution*, WHO, 2016, pp1- 8

[81.], Davis S., Boundy R., Stacy C and Diegel S, *ORNL Transportation energy - Data Book*, 33rd edition, 2014, pp 2-10

[82.], Dowlatabadi H., Lempert R. and Zhao J., *Distinct motivations travel, patterns of one-way and two-way carsharing in Vancouver (Canada)*, c*onvenience, savings, or lifestyle*, transportation research part D, 71, 2019, pp- 141-152.

[83.], Dreyer S., McCoy S., Teisl M. and Walker I., *Australian carbon pricing before after 2013*, Climate change 5, 2015

[84.], Duran D., Ferri A., Kuttler T., Magelund J., Mogele M., Nitschke L., Servou E., Silva C. and Villeneuve D., *what is interdisciplinarity in Practice*, 2020

[85.], Defila R., Giulio A. and *Olbertz, H., interdisciplinarity and disciplinarity in between the subjects*, Germany, 1998, pp. 111–137.

[86.], *Environmental protection agency (EPA) US, source of (GHG) greenhouse gas emission*, 2020 pp 1- 20

[87.], *Economic Contributions Accessed*, OICA, 2019, pp 2- 10

[88.], Eggert A. and Sperling D., *California climate, energy policy and transportation, e*nergy *Strategy* 5, 2014, pp- 88-94.

[89.], Envall P., Henriksson G. and Johansson F., *workings of a Progressive Mobility Plan, private car restricted and Mobility-served neighbourhoods*, 2019

[90.], Evans J. and Karvonen A., *urban laboratories and governance of low-carbon futures*, 2014, pp- 413–430

[91.], *European Commission. a concept for sustainable urban mobility plans*, 2019

[92.], Fagnant D, Kockelman K and Bansal P, *operations of a shared autonomous vehicle fleet for the AU Texas market*, 2015, pp 1-2

[93.], *Foresight government of science, the of future mobility*, 2019, pp -90-146

[94.], FICCI, *India road map on low carbon and sustainable mobility – decarbonatization of*

*Indian transport sector*, 2021, pp 1 -116

[95.], Figenbaum E., *Norway's supercharged (EV) electric vehicle policy, enviro., Innovation and Societal Trans.- 25*, 2017, pp - 14-34.

[96.], Farrell E., Jones D., Kammen M., Plevin J., Turner T. and O'Hare M., *Ethanol Can Contribute to Energy and Environmental Goals*, Science 311, 506-508, 2006

[97.], Firnkorn J. and Muller M., *the environmental effects of new free-floating car-sharing systems*, ecological Economics, 2011, pp -1519-1528

[98.], Flipo A., Lejoux P., Ortar N., Ovtracht N., Lecorvec S. and Stanica R., *coworking, a way to achieve sustainable mobility, interdisciplinary research project*, 2018.

[99.], Fraedrich E. and Lenz B., *automated driving - individual and societal aspects. transp. res.* rec. J. Transp. Res. Board Natl. acad., 2014, pp - 64–72

[100], Flander D., Hahne U., Kegler H., Lang D., Lucas R., Schneidewind U., Simon H., Brodowski S., Wanner M. and Wiek A., *a resilience and real-life laboratories as key concepts for urban transition research*, 2014, pp - 284–286

[101], Finke P., the underestimated knowledge of the Lay; oekom verlag: *Germany*, 2014.

[102], Franz Y., Tausz K. and Thiel S., a *qualitative case study comparison of living lab., Rev*. 2015,

[103.], Georen P., Hesselgren M., Ritzén S., Sopjani L. and Stier J., *light electric vehicle sharing in Sweden case study*, transportation research part - d:71, 2009, pp- 207-221

[104.], Greenblatt B., and Saxena S., *autonomous taxis could greatly reduce greenhouse-gas emissions of US light-duty vehicles*, nature climate change 5, 860, 2015

[105.], Guivarch C. and Rogelj J., *carbon price variations in 2°C scenarios explored*, carbon price Leadership Coalition, 2017

[106.], Galvin R., *modelling future electrical vehicle journey on a decarbonized United States (US) electricity grid, electric vehicles too big and heavy*, energy policy-161, 2022

[107.], Gnann T., Münzel C., Plotz P. and Sprei F., *financial incentives effect on (EV) electric* *vehicle sales: a global and European analysis*, energy eco., 104493, 2019.

[108.], Gerike R., Nazelle A., Wittwer R. and Parkin J., *health and the environment: walking and cycling for Transport*, 2019, pp- 1–6, 123

[109.], Grunwald A. and Padmanabhan M., *a transdisciplinary approach to the process of socio-technical transformation, in transdisciplinary research and Sustainability*; UK, 2018, pp. 35–52.

[110.], Grosvenor A., *qualitative research in the Transport sector, ICTSQI* Grainau, Germany, 2000

[111.], Hogt R., Balm H. and Warmerdam M., d*esigning light (EV) electric vehicles for urban freight transport, 2017*, pp 1-10

[112.], Hughes J., *Drill baby drill and hugh*es, *can unconventionally fuels usher in a new era of energy abundance,* post carbon institute, 2013, pp 3-20

[113.], Hong H. and Wang M., *Energy Policy 43,* 2012, pp 199-214

[114.], Hoekstra A., u*nderestimated potential of (BEV) battery electric vehicles to reduce emissions,* Joule 3, 2019, pp - 1412-1414,

[115.], Hisashi K. and Shah S., in developing countries: *analysing travellers' attitude towards ride-hailing services: case study of Lahore*, IATSS *research*, 2021

[116.], Hensher A., Ho Q. and Reck J., *mobility as a service and private car use: evidence from the Sydney MaaS trial*, Transportation Research Part A: Policy and Practice 145, 2021, pp 17- 33,

[117.], Hall D., Nicholas M. and Bernard R., *working paper: Guide to electrifying ride-hailing vehicles for cities.* International Council for Clean Transportation, 2021

[118.], Hanson S., *gender and mobility: new approaches for informing sustainability, 2010, pp 5–23.*

[119.], Hulsmann F., Miles A., Moore N. and Muir S., *studying transport and travel behaviour through life histories, strategies for Sustainable Mobilities*, London, UK, 2013, pp. 173–188.

[120.], *International energy associations outlook (IEA), publication,* 2020, 2021 and 2022

[121.], IEA, *CO2 emissions from fuel combustion Highlights*, 2016, pp 4-166

[122.], Icek A, *Attitudes personality and behaviour, 2nd edition. NY: AA Open University Press,* 2018, 142-144

[123.], *International Monetary Fund (IMF), WEO Washington, D.C. 2017*, 2018 pp 58-60

[124,], *International energy association*, *Innovation Gaps*, IEA, Paris, France. 2019, pp 4- 20

[125.], *International energy association*, *Advanced Biofuels- Potential for Cost Reduction,* IEA, Paris, France, 2020, pp 2-12

[126.], *International energy association*, *Tracking Transport* 2020. IEA, Paris, France, 2020b.

[127.], *International energy association*, *Electric vehicles,* IEA, Paris, France, 2021

[128.], *International energy association*, *ETP Clean Energy Technology Guide*, IEA, Paris, France, 2021, pp – 4 - 25

[129.], *International energy association*, *Global EV Outlook, Accelerating ambitions despite the pandemic*, IEA, 2021, pp - 10 - 26

[130.], *International energy association*, *Global Hydrogen Review, IEA*, Paris, France, 2021

[131.], *International energy association*, Net Zero by 2050, Paris, France, 2021 pp – 5 - 26

[132.], *International energy association*, Transport Biofuels. IEA, Paris, France, 2021, pp 6 - 30

[133.], *International energy association*, Trucks and Buses. IEA, Paris, France, 2021, pp 10 - 21

[134.], *International Renewable Energy Agency* (IRENA) s*mart charging for (EV) electric vehicles, Innovation Outlook,* Abu Dhabi, 2021

[135.], *International Council on Clean Transportation* (ICCT), *decarbonizing road transport by 2050, accelerating global transition to (ZEV) zero-emission vehicles,* ICCT, 2021

[136.], International Council on Clean Transportation (ICCT), g*lobal comparison of the life cycle (GHG) greenhouse gas emissions of combustion engine (CE) and electric passenger cars,* ICCT, 2021

[137.], Itsubo N., Karkour S., Lin C., Maaoui M. and Rachid S., *life cycle assessment (LCA) in Africa* environments 8, 2021

[138.], Jokinen J P, Mladenovic M and Sihvola T, *flexible transport service pilot in the Helsinki Capital region*, 2019, pp- 123–133.

[139.], Jolanta M., Liedtke C., Nordmann J. and Rohn H., *user-driven innovation for sustainability*, International Journal, 2012, pp- 106–118

[140.], Juujarvi S. and Pesso K., a*ctor roles in an urban living lab: Innov. Manag*. Rev. 2013 pp -22–27

[141.], Kuhlman T. and Farrington J., *What is sustainability*, MDPI, November 2010, pp 3-7

[142.], Kishimoto P, Paltsev S and Karplus V., *The Global Energy CO2 Emissions and Economic Impact of Vehicle Fuel Economy Standards, Journal of Transport Economics and Policy*, 2015, pp. 1-24

[143.], Knupfer S., Hensley R., Hertzke P., Schaufuss P., Laverty N. and Kramer N., electrifying insights: automakers can drive (EV) electrified vehicle sales and profitability, McKinsey and Company, 2017, pp 2-25

[144.], Kishimoto P., *Transport demand in China: Methods for estimation, projection and policy assessment, MIT*- 2018, pp 189-203

[145.], Knittel C., *american economic review* 101, no.7, 2011, pp 2-12

[146.], Knittner N., Felix L. and Kammen D., "*Energy Storage Deployment and Innovation for the Clean Energy Transition -Nature Energy 2"*, 2017 pp 3-20

[147.], Karla N. and Susan P., "*miles of driving to demonstrate AV reliability and corporation", 2016*, pp 1-13

[148.], Kockelmanb K., Levina M., Boylesb S. and Lib T., "modelling *framework for shared autonomous vehicle (AV) dynamic-network loading and dynamic-ride sharing"*, 2017, pp 7-9

[149.], Kacperski C., Klingert S., Kirpes B., Kutzner F., and Ulloa R., *Impact of incentives for greener battery electric vehicle charging – A field experiment*, Energy Policy 161, 2022

[150.], Kivimaa P. and Kern F., *Innovation policy for sustainability transitions, creative destruction or mere niche support, r*esearch policy 45, 2016 pp 205-217

[151.], König A., Gebhardt L. and Brost M., *an Inter and transdisciplinary approach to developing and testing a new sustainable mobility system*, 2019

[152.], Konig A, Karnahl K, Gebhardt L and Klotzke M, Schorndorf R., design demand controlled mobility together. In Proceedings of the 12th German Local Traffic Day, Koblenz, Germany, 2018.

[153.], Kolleck A., *Participate online, perspectives and challenges of internet-based participation Processes,* newsletter network civic participation, 2016, pp 1–8.

[154.], Klein T., i*nterdisciplinarity history, theory and practice, WSUP*: Detroit, MI, USA, 1990.

[155.], Konig A., Karnahl K., Gebhardt L. and Klotzke M. and Schorndorf R., design demand-controlled mobility together. In Proceedings of the 12th German Local Traffic Day, Koblenz, Germany, 2018.

[156.], Kramer S.*, time for mobility: Spatial disparities in individual time use for mobility in Germany; Franz Steiner Verlag: Stuttgart*, Volume 138, Germany, 2008

[157.], Lutz G. and Philip M., *Electric Vehicles in Shared Fleets*, 2022, pp.125-144

[158.] Lane B., and Colin S., *research in transportation business and management valuing Transportation, measuring: what Matters for Sustainability*, 2013 pp 1 – 10

[159.], Li Y and Hesary T., *economic feasibility of green hydrogen and (FCEV) fuel cell electric vehicles for road transport in China,* energy policy – 160 -112703, 2022

[160.], Lima A., Litster S., Samaras C., Whiston M M., Whitefoot K. and Whitacre F., *Expert elicitation on paths to advance fuel cell electric vehicles. Energy Policy 160*, 112671, 2022

[161.], Lima A., Samaras C., Whitacre F., Whiston M., Litster S. and Whitefoot F., *expert elicitation on paths to advance FCEV (fuel cell electric vehicles),* energy policy-160, 2022

[162.], Labee P., Liao F. and Rasouli S., *the implications of mobility as a Service for urban emissions. Transportation Research Part D*: Transport and Environment 102, 103128, 2022

[163.], Lade E., Sperling D., Witcover J. and Yeh S., *low carbon fuel policies, status and future directions*, energy policy - 97, 2016, pp -220-234.

[164.], Lipman E., e*merging Technologies higher fuel economy, automobile standards, environment and resources* 42, 2018, pp- 267-288.

[165.], Levine A., *evolution of the accessibility concept*, Transport part d, 2020

[166.], Liyanage S., Dia H., Abduljabbar R., Bagloee A., *flexible mobility on-demand: an environmental scan.* sustainability 2019, pp -11- 15

[167.], Murphy C., Matteo M., Paige J., Trieu M., and Yinong S., *electrification futures: scenarios of power system evolution and infra development for US, NREL*, 2021, pp 3-118

[168.], Mariano G. and Mario M., *possible actions and policies for* sustainable *mobility*, 2020, pp1- 39

[169.], Muratori M, *future integrated mobility-energy Systems - a modelling perspective,* 2022, pp 1-20

[170.], Matthew M., Nicholas R. and Fitzgerald R, *"the highly integrated vehicle ecosystem (HIVE), a platform for managing the operations of on-demand vehicle fleets"* NREL, 2021, pp 1-27

[171.], Machielsen C., Rieck G., and Duin R., "*automotive the future of mobility, of EVS30 Symposium, 2017* (pp. 1-14)

[172.], *MIT researcher, international parking and mobility Institute,2020*, pp 30-39

[173.], Marcel C., *international battery, Hybrid and FCEV*, 2017. pp 560-567

[174.], *McKinsey center* for future mobility, *mobility is at our doorstep,* 2020, pp 3-117

[175.], Macharis C., Boureima F., Mierlo J., Messagie M., and Coosemans T., a r*ange based vehicle (LCA) life cycle assessment incorporating variability in environmental assessment of vehicle technologies and fuels"* 2014, pp 1468-1579

[176.], Meyer L., Pachauri R. and Rajendra K., *Synthesis Report: Assessment report of* *inter-governmental climate change, 2014 Geneva – Switzerland, 2014*, pp. 101-105

[177.], Mackenzie D. and Heywood J., *On the Road toward 2050: potential for substantial reductions in LDV Energy Use and GHG, MIT, 2015*, pp 25-290

[178.], Moultak M., Lutsey N. and Hall D., *transitioning to (ZE) zero emission heavy duty freight vehicles*, ICCT, San Francisco, USA, 2017

[179.], Masron A. and Subramaniam Y., *impact of economic globalization on bio-fuel in developing countries*, 2021

[180.], Matyas M. and Kamargianni M., The potential of mobility as a service bundle as a mobility management tool. Transportation, 20218

[181.], Milakis D., Arem B. and Wee B., *Policy and society related implications of automated driving: A review of literature and directions for future research,* Journal of Intelligent Transportation Systems 21, 324-348, 2017

[182.], MacKenzie D., Leiby P. and Wadud Z., *Help or hindrance, The travel, energy and carbon impacts of highly automated vehicles,* Transportation Research Part A: Policy and Practice 86, 2016, pp -1-18.

[183.], Morris E., *Intra metropolitan location, access, activity patterns and subjective well-being,* 2019 pp - 89, 228–242.

[184.], Martin P., *public participation in healthcare, people, social and health 2008,* pp - 35–54

[185.], Nykvist B. and Nilson M., r*apidly falling costs of battery packs for (EV) electric vehicles-nature climate change 5,* 2015, pp 329–332.

[186.], *NHTSA Run-off-road crashes DOT HS 811 500,* 2011, pp 1-26

[187.], Nemet G. and Sierzchula W., l*essons California's Zero Emission Vehicle (ZEV) regulations,*2015, pp -213-224.

[188], Pohl C., *Die Auseinandersetzung zwischen den vielfältigen transdisziplinären Forschungsansätzen ist gefragt! Gaia-Ecol. Perspect. Sci. Soc*. 1999, pp- 228–230

[189.], Rifkin J., *zero marginal cost society, the internet of things, collaborative, commons and* *eclipse of capitalism",* 2014, pp 1-2

[190.], Rieck F., Ebbers G. and Boonstra S., *Analysis of a fictive active e-trailer RU of AS and e-Traction – 2017*, pp 1-6

[191.], Rieck F. and Raak I., *In houde lijke eindrapportage eMobility-Lab*, *Automotive the Future of Mobility Hogeschool Rotterdam*, 2014, pp. 1-10

[192.], Rieck F., Machielse K. and Duin R., will automotive be the future of Mobility? Striving for six zeros", 2020, pp.1-15

[193.], Rifkin J., *zero marginal cost society IoT (internet of things), commons, collaborative and eclipse of capitalism",* 2014, pp 1-2

[194], Rafiu A., Daniels C. and Sovacool K., t*ransitioning to automated electrified and shared mobility in African (Johannesburg, Nairobi, Kigali and Lagos)*, Journal of transport geography-98, 2022

[195.], Rodier C., *The Effects of Ride Hailing Services on Travel and Associated Greenhouse Gas Emissions*, Institute of Transportation Studies, UC Davis, Davis, USA, 2018

[196.], Rodier C, *International Modelling: transit, land and auto pricing strategies reduce (VMT) vehicle miles travelled and (GHG) Greenhouse Gas Emissions*, Transportation Research Record 2132, 2009, pp -1-12.

[197.], Richardson C, *Sustainable transport: Analysis frameworks. J. Transp. Geogr*. 2005, 13, pp. 29–39

[198.], Reurbanisierung B. and Urbanczyk R., *Interdependenzen zum Strukturwandel, In Reurbanisierung - Materialität und Diskurs in Deutschland; Springer VS*: Wiesbaden, Germany, 2012; pp. 22–33.

[199.], Chakraborty S., *selected aspects of sustainable mobility reveal implementable approaches and conceivable actions*, 2021, pp 1-31

[200.], Singh S., c*ritical reasons crashes investigated in the NMVCCS, NHTSA, Washington, DC:* 2015-02, pp 1-2

[201.], *SLoCaT -Transport and Climate Change Global Status*, 2018, pp 20-60

[202.], Swarco, *Sustainable future mobility definition*, 2021, pp 1-10

[203.], *Statista Publication, Future mobility, 2022,* pp. 1-20

[204.], Scarborough B., Burns L. and Jordan W., "*Transforming personal mobility"*, earth island institute, Columbia University, 2012 pp.3-42

[205.], Schmidt O., Hawkes A., Gambhir A, and Staffell I., f*uture cost of electrical energy storage (EES) on experience rates"* 2017, pp 5-25

[206.], Simbeck D. and Chang E., *hydrogen supply: cost estimate for hydrogen pathways scoping analysis, NREL/SR-540-32525*, 2022, pp 21-35

[207.], Sen B,, Ercan T. and Tatari O., *a battery electric truck – Life cycle cost, emissions and externality analysis of alternative fuel heavy-duty trucks in US,* Cleaner Production - 141, 2017, pp- 110-121.

[208.], Sperling D., 3 *revolutions: steering electric vehicles, automated and shared vehicle for better future, Island press,* Washington DC, 2018

[209.], Shaheen S., the potential of ride hailing and pooling in share mobility, 3 r*evolutions: steering automated, shared and (EV) electric vehicles for a better future. Island press,* Washington DC., 2018

[210.], Slowik S. and Lutsey N., *The continued transition to electric vehicles in U.S. Cities:* the International Council on Clean Transportation (ICCT), San Francisco, USA., 2018

[211.], Schneidewind U. and Augenstein K, analysing *a transition to a sustainability-oriented science system in Germany. environ. innovation. Soc. Transit*. 2012, pp - 3, 16–28.

[212.], Suchanek M. and Szmelter A., generation Y's e*nvironmental aspects of sustainable mobility, Sustainability* 2019, pp 11

[213], Schuurman D. and Marez L., *Structuring user involvement in pane Living Labs,* Rev. 2012, pp - 31–38

[214.], Threlfall R., a*utonomous vehicle (AV) readiness index, KPMG International*, 2019, pp 3-51

[215], *Toshiba, CASE (connected, autonomous, share mobility and electric vehicle) trends for next generation vehicles and approach to automotive semiconductor devices, 2019*, pp 1-7

[216.], Thomas E. and Threlfall R, r*eimagine-places-mobility-as-a-service, KPMG UK* 2017, pp 2 – 25

[217.], Tsamos A., *Alternative Drivetrain for Future Freight Trucks*, 2020, pp.8-22

[218.], Threfall R., *Autonomous vehicle (AV) readiness index, KPMG Int.*, 2019, pp 3-51

[219.], Taylor., *Opportunities and pitfalls in new governance spaces*, 2007, 44, 297–317

[220.], *UNECE* nexus, *sustainable mobility and smart connectivity,* 2021, pp 1 – 154

[221.], *UNECE, carbon neutrality in the UNECE region: integrated life cycle assessment of electricity source,* 2022, pp 1-108

[222.], *UNECE* nexus, *sustainable mobility and smart connectivity,* 2021, pp 1 – 154

[223.], *U.S. DOT, Household spending on transportation – In transportation economic trends, Washington, D.C*, 2018, pp 1-6

[224.], *U.S. EIA, energy outlook 2018, Washington, D.C.: U.S. DOT*, 2018, pp 290-402

[225.], *UN DoE and social affairs - Population Div.WPP:*2017 pp 2-4

[226.], *US energy information administration, International Energy outlook with projection 2040,* Washington DC, 2016, pp 6 – 99

[227.], Velde J., and Rieck F., *in actual operational costs of (ET) electric transport, applied science*, EVS -27, 2013, pp 1-10

[228.], Viegas J., Martinez M and Crist P., Shared Mobility: Innovation for Liveable Cities. OECD International Transport Forum Corporate Partnership Board, Paris, France, 2016

[229.], Vanoutrive T. and Cooper E., *transportation justice theory, issues of paternalism and production*, part A 2019, pp 112–122

[230.], Verlinghieri E. and Schwanen T., *Transport and mobility justice: Evolving discussions. J. Transp. Geogr*. 2020

[231.], Voorberg H., Bekkers M. and Tummers G., a *systematic review of co-creation and co-production:Embarking on the social innovation journ*ey, Rev. 2015,

[232.], *World economic forum, why future of mobility starts with mobility*, 2021, pp 1- 8

[233.], World Bank Group, *State and Trends of Carbon Pricing*, Washington, DC, USA, 2019

[234.], Weber M. and Rohracher H., *legitimizing research and innovation policies for transformative change:* research policy 41, 2012, pp -1037-1047.

[235.], WCED, (*World commission on environment and development), Oxford University* UK, 1987

[236.], *World Commission on Environment and Development. Our Common Future; Oxford University*: Oxford, UK, 1987.

[238.], World in transition, in social contract for a great transformation, scientific advisory board of the federal WBGU, *Berlin, Germany*, 2011.

[239.], Yang Z., Chen Y. and Isenstadt A., *fuel efficiency technology trend assessment for LDVs in China: Advanced Engine Technology*, 2018 pp 2 -10