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Alternative and renewable energy and emerging vehicle technologies in Public Transport: Air quality and climate co-benefits for transport

(Background Paper for EST Plenary Session 3)

Final Draft

This background paper has been prepared by Jan Deman & Kulwant Singhi for the 13th Regional EST Forum in Asia. The views expressed herein are those of the authors only and do not necessarily reflect the views of the United Nations.

UNCRD 13th Regional EST Forum in Asia

10-11 November 2020

Background Paper

"Alternative and renewable energy and emerging vehicle technologies in Public Transport: Air quality and climate co-benefits for transport"

Jan Deman & Kulwant Singh

Busworld Foundation

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Foreword

Buses represent a significant part of any public transport system and are often the only public transport mode in many cities. Although the transport sector contributes less than 15% of the global greenhouse gas emissions, bus fleets contribute to city pollution only in very small part, responsible for 5% of transport emissions. However, the fact remains that over 50% of buses across South East Asia are still of Euro/Bharat III standard or older; this leaves much room for improvement.

In this context, the Busworld Foundation was created to promote the large-scale deployment of clean bus systems as the backbone of urban mobility. This places fleet renewal at the top of the political agenda.

A cleaner bus system offers a sustainable solution that public transport operators are committed to deliver. Therefore, national and regional governments and cities should put in place clear policies that promote the shift towards a more sustainable and integrated mobility, easing and encouraging the deployment of bus and coach dedicated infrastructure. This should favour the combination of public transport by bus and coach with last mile solutions, such as demand responsive systems, cycling and walking.

The objective is to create a multiplier effect on quality of life and the livability of cities. Specific reduction targets for air pollution and noise levels combined with financial supporting schemes at regional, national and/or international level, and accessible to as well public as private sector, have proven highly effective in supporting modal shift as well as clean bus deployment and fleet renewal. The Busworld Foundation and its partners in the industry provide the knowledge and materials to assist public transport stakeholders in choosing the right solution for their operational scenario and implementing a suitable strategy to reduce transport emissions and increase passenger transport services.

Jan Deman

Introduction

Sustainable transport is fundamental to progress in realizing the promise of the 2030 Agenda for Sustainable Development and in achieving the 17 Sustainable Development Goals. Sustainable transport supports inclusive growth, job creation, poverty reduction, access to markets, the empowerment of women, and the well-being of persons with disabilities and other vulnerable groups. It is also essential to our efforts to fight climate change, reduce air pollution and improve road safety.

About 44 million people are being added to Asia's urban population every year, equivalent to 120,000 people a day. ADB has estimated that 80% of Asia's new economic growth will be generated in its urban economies since this is where most jobs and employment opportunities are located. These trends are placing an enormous strain on transport and mobility in urban areas. Motor vehicle fleets are already doubling every 5 to 7 years.

To provide sustainable urban transport solutions, the Asia and Pacific region needs to address rapid motorization which is a major cause of congestion and pollution. Road congestion already costs Asian economies an estimated 2%–5% of gross domestic product (GDP) every year due to lost time and higher transport costs. The region's cities suffer from the highest air pollution levels in the world, with as much as 80% attributable to transport.

As some large Asian cities are discovering, construction of urban roads will not alone provide a solution. Construction of new roads leads to more purchases of private vehicles which eventually leads to the roads again becoming congested. Moreover, further road building faces severe practical limitations and escalating costs due to the shortage of land in urban areas.

The South East Asia region comprising of 11 countries that include: Malaysia, Cambodia, Indonesia, Philippines, East Timor, Laos, Singapore, Vietnam, Brunei, Burma and Thailand, has been experiencing high economic growth on one side and facing critical problems of environmental sustainability on the other. The population increase in the ASEAN region has caused rapid urbanization and the fast increase in the private vehicle ownership in line with economic growth which is the cause of such concerns such as air pollution and traffic congestion. Most of these countries do not strategically respond to these challenges of urban transport. Countries such as Indonesia do not have National Urban Transport Policy. The lack of public transport services causes a serious barrier for economic development and sustainable growth. Therefore, most countries in the region require systematic development of public transportation.

Indonesia has 15 major cities with over 1 million inhabitants. Public transport in these cities is scarce and unreliable, with a low usage rate (5%-20% of trips). Hardly any consideration is given to non-motorized transport. Cities need to enhance their technical expertise to plan, design, implement, and operate public transport systems; increase the funds to develop mass transit systems; and strengthen institutional capacity to integrate transport and spatial planning more closely. Like other South-East Asian countries, Indonesia has experienced a drastic rise in motorised transport over the last two decades, caused by subsidized fuel, rising incomes, and low interest rates for vehicle loans.

In combination with the limited infrastructure, rapid motorization exacerbates the adverse environmental impact of transport: the sector currently accounts for 70%-80% of oil outdoor air pollution in the country (including particulate matters) and 23% of greenhouse gas emissions. Sound transport strategies and policies are crucial to boosting Indonesia and other ASEAN countries' economic growth and achieving the Sustainable Development Goals, specifically Goal 9 to ''build resilient infrastructure, promote sustainable industrialization and foster innovation'' and Goal 11 to ''make cities inclusive, safe, resilient and sustainable.'' There are several important priorities which the countries in the region must tackle in order to develop a more sustainable transport system:

- Creating efficient, affordable, and green public transport networks in the main urban areas by building more **Bus Rapid Transit systems and by investing in energy-efficient, low-emission public transport vehicles**.
- Stimulating the modal shift towards collective transport modes
- Developing infrastructure, policies, and communications to encourage the use of non-motorized transport, including safer corridors for pedestrians and cyclists
- Promoting the implementation of stricter vehicle emissions standards to improve vehicle energy efficiency
- Restricting private car use through the implementation of fees in heavily congested areas
- Encouraging the use of electric vehicles through incentives, such as tax exemptions and the construction of a wide network of charging stations
- Enhancing private sector participation and limiting the role of State-Owned Enterprises to foster a more competitive environment. Implementing these strategies requires strong commitment and effective collaboration at all levels of government: central, provincial, and local and also involving the private sector for a vital role in implementation.

Chapter 1. Identifying the Problem

Transport is fundamental to development in a large-scale, global sense. At the same time, it has a profound and personal impact on individual lives. In many cases, transport involves choice—whether to move or to stay in place, whether to walk, cycle, take public transport or a private car. The choice is also in many situations severely limited by poverty; social exclusion; and national, regional, or local circumstances. The transport options available in a country reflect its level of development. At the same time, transport is a driver as well as a marker of economic development. It enables individuals and communities to rise out of poverty and overcome social exclusion, connecting goods to markets and linking rural areas and market towns to large cities and the global marketplace.

Sustainable transport may be defined as "the provision of services and infrastructure for the mobility of people and goods— advancing economic and social development to benefit today's and future generations—in a manner that is safe, affordable, accessible, efficient, and resilient, while minimizing carbon and other emissions and environmental impacts."

Transport is not an end in itself, but rather a means allowing people to access what they need: jobs, markets, social interaction, education, and a full range of other services and amenities contributing to healthy and fulfilled lives. Our focus is not on providing mobility based on individual motorized transport and improved traffic speed, but to the idea of **access through transport**, prioritizing people and their quality of life, with strong attention to safety and social equity.

1.1 Situation in South East Asia

Rapid urbanization and economic development with increasing demand for travelling has made urban transportation the prominent environmental concern for local, national, and global decision-makers. These issues vary from air pollution, congestion, noise, accidents, and travel time. Evidence shows that air pollution from transportation not only targets local environments but, through increasing greenhouse gas emissions, it now has become a global concern.

According to the UN 2011 Revision, it is expected that about 23 out of 37 megacities (over 10 million population) will be located in Asia by 2025. This indicates a clear trend of accelerated urban concentration with extensive rise in CO_2 emissions from the Asian countries.

The regions of East and Southeast Asia are home to a third of the world's population. They provide some of the most daunting transport and development challenges, but also some of the most innovative solutions. By 2030, China will have over 200 cities with more than one million population, placing enormous pressure on roads and streets to accommodate increasing mobility needs. Unfortunately, the regions are becoming increasingly car-oriented, with many urban plans and road designs ignoring the needs of pedestrians, cyclists, and transport users. China is now the world's largest car market, with a staggering growth of more than 13 percent per year. Indonesia's car market is also growing by around five percent per year and is seeing much more rapid growth in motorcycles and scooters competing with cars for road space, with major surges in road fatalities and injuries. Fortunately, China and Indonesia are also providing inspiring best practices. China has added hundreds of kilometers of high-quality mass transit, primarily metro and bus rapid transit, has invested heavily in cycling infrastructure and leads the world in bike share. Indonesia was one of the first cities in Asia to implement a bus rapid transit system, Transjakarta, in 2004.

In Southeast Asian countries (SEA), road transport accounts for the main energy consumption and CO_2 emission. Air pollution is a major concern in densely populated cities such as Bangkok, Manila, and Kuala Lumpur. The South East Asian countries are experiencing different prospects of sustainability in the transportation sector. However, according to the UNESCAPE report, the countries show different levels of improvements in transportation infrastructure.

The data from SEA countries show that the highway system was expanded to 24, 071 km in 2010 compared with 23, 594 km in 20036. The roads network in SEA is greatest in Thailand, with 5,111km of total road network in 2010, followed by Indonesia with 4091 km and Philippines with 3,367 km6 (Figure 1). Singapore maintained a constant road network mileage of 19km between SEA countries with no road expansions between 2004 and 2010. In terms of road construction, Lao PDR with construction of 479 km of road network and Indonesia with 139 km showed the greatest growth. Analyzing data also showed that total road mileage declined by 150km in the Philippines because of the regional flood in 2011.

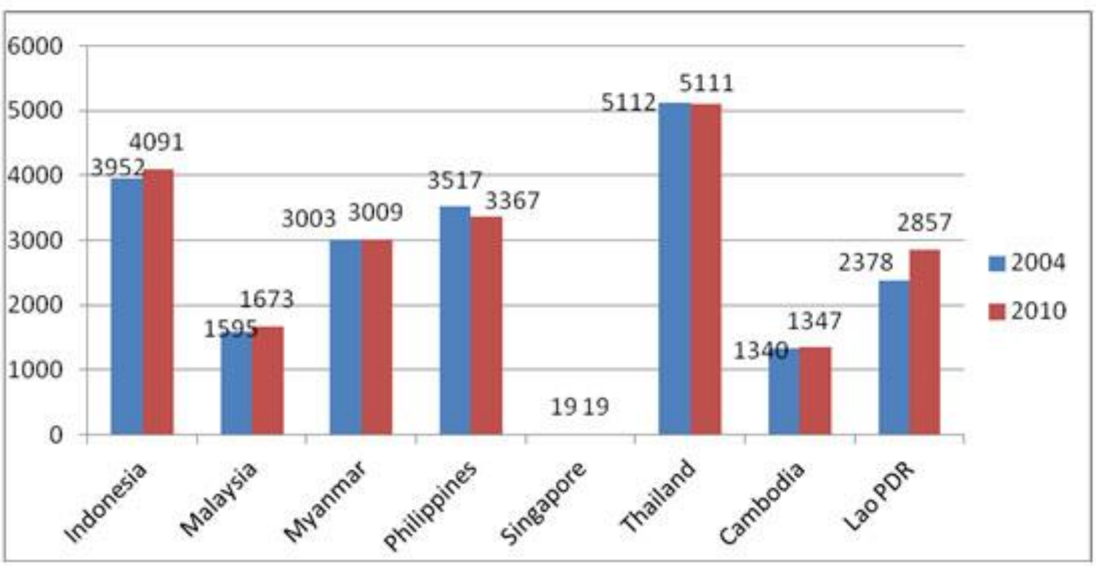


Figure 1: Total road network in SEA countries
Source of data: World Bank, 2013

Following road expansion, car ownership also increased to 43 per 1000 persons in SEA. However, it is much lower than in high income countries (434 per 1000 people in Europe or 606 per 1000 people in North America). In 2010, the highest rate of car ownership is observed in countries with better economic conditions, such as Brunei Darussalam with 649.14 cars per 1000 people, Malaysia with 325 cars per 1000 people, and Singapore with 117 cars per 1000 people (Figure 2). Comparing the data with 2003 indicated that between 2003 and 2010 car ownership is increased mostly in Brunei Darussalam with 59% and Malaysia with 23%. This number is 8.68% for Indonesia, 4.69% for Singapore, 0.47% for Myanmar, and 3.05% for Thailand[6].

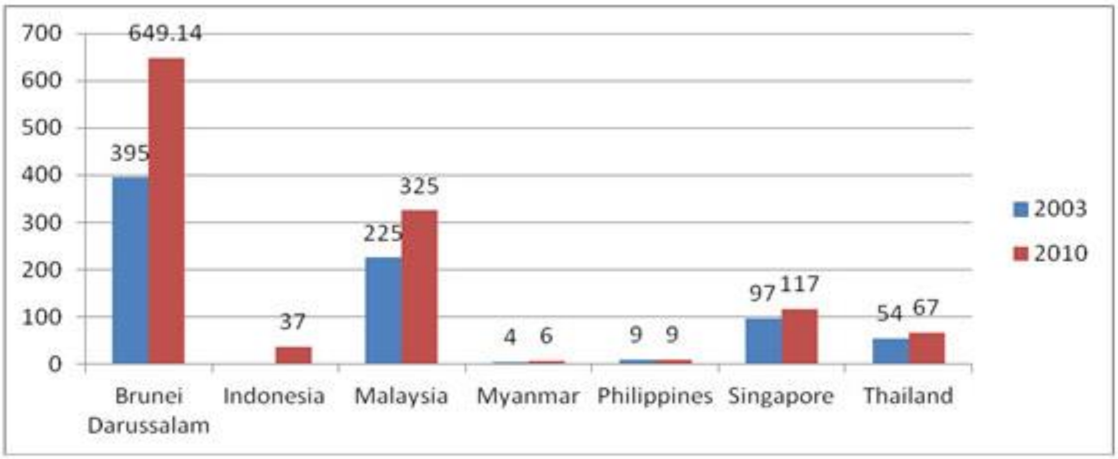


Figure 2: Car ownership per 1000 people in SEA countries
Source of data: World Bank, 2013

The transport sector's energy consumption increased by 30226 million tons of oil equivalent in the SEA region from year 2000 to 2010. The road transport sector in SEA consumed about 86,504 million tons of oil equivalent energy in 2010, which is 93% of the total energy consumption in the transportation sector[5]. This amount is 4.95% of total global energy consumption in the road sector. According to World Bank[6] data, Indonesia, Thailand, and Malaysia, followed by Viet Nam, accounted for the most road related energy consumption in SEA in 2010 (Figure 3). Interestingly, in Malaysia 99.79%, in Thailand 99.13%, and in Viet Nam 97.54% of total transportation energy consumption is by the road sector[5].

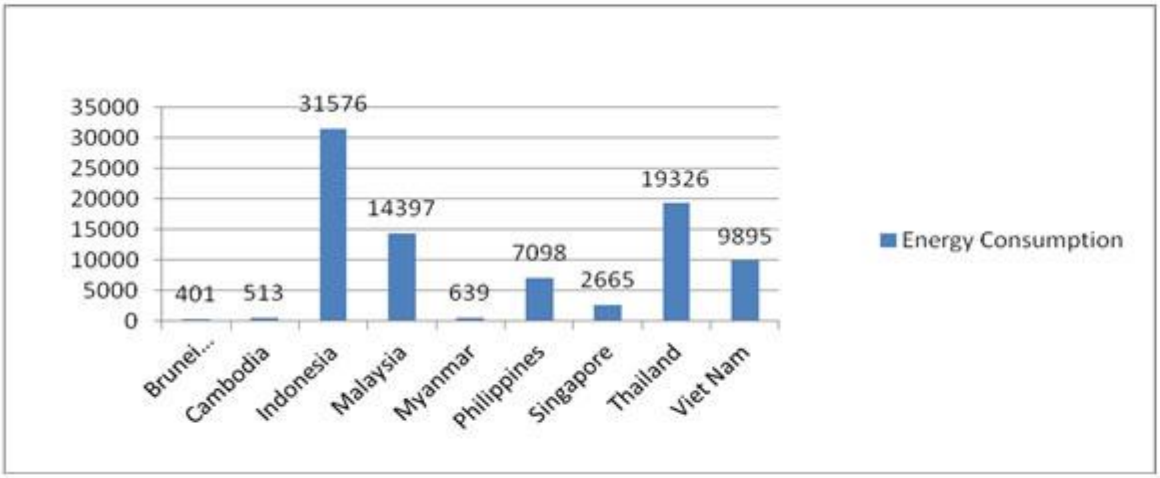


Figure 3: Road transport total energy consumption in SEA countries in 2010
Source of data: World Bank, 2013

Along with increases in energy consumption, CO_2 emissions from the transport sector also show alarmingly increasing rates of use (Figure 4). CO_2 emission from SEA countries almost doubled in the two decades between 1990 and 2010. In 2010, CO_2 emission from transport sector was 252 million tons, which was a 66 million ton increase since 2000. The road transport sector accounted for 93% of CO_2 emission from the transportation sector. The highest amount of CO_2 emission was observed from Indonesia, then Thailand, Malaysia, Philippines, and Viet Nam[5].

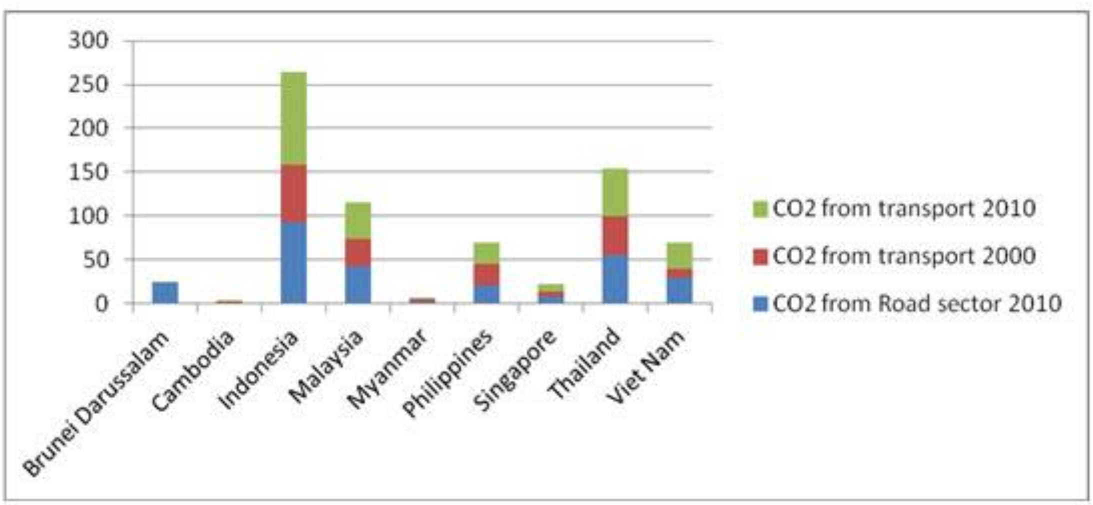


Figure 4: CO_2 emission from SEA countries (million tons of CO_2)
Source of data: UNESCAPE, 2013

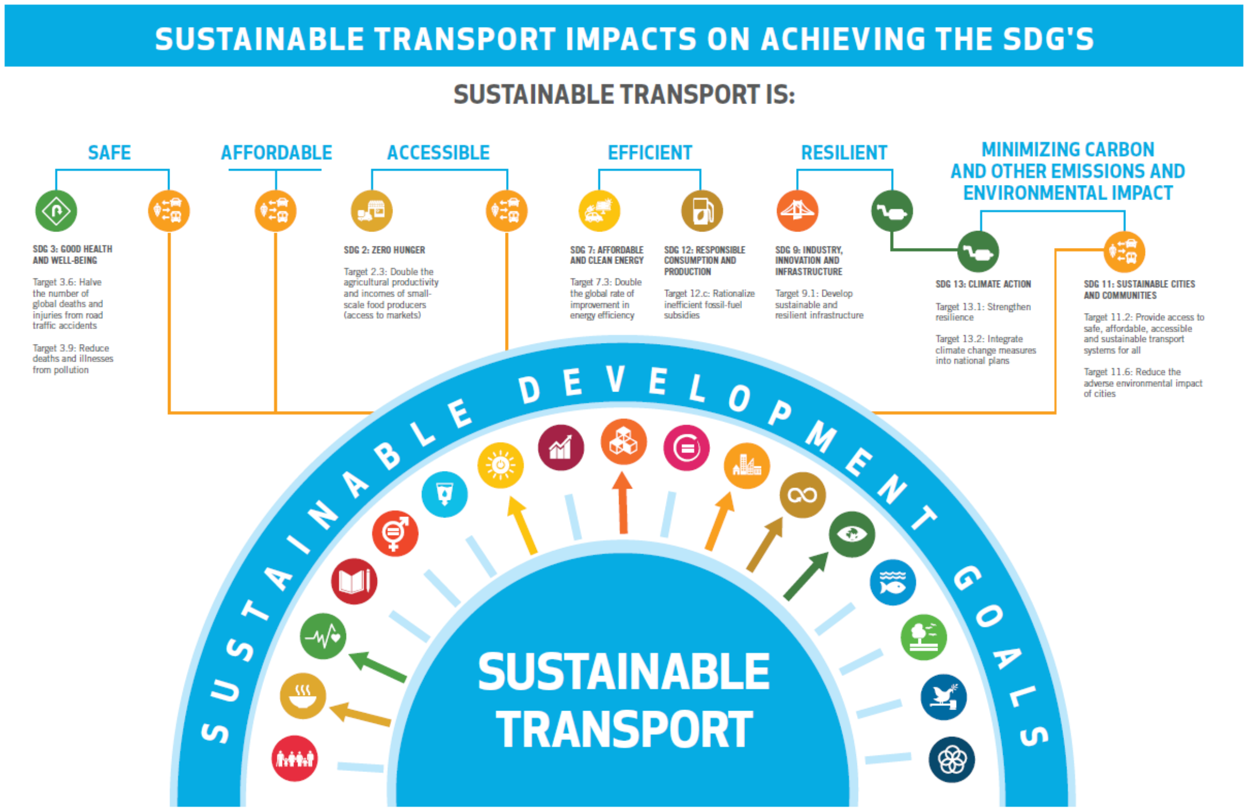
1.2 Transport Link to the SDGs

The evolution towards climate neutral public transport contributes to the SDGs as described in the 2030 Agenda for Sustainable Development, via

- Improving the performance of society in terms of energy efficiency (Target 3.6)
- The reduction of air pollution (Target 3.9)
- The mitigation of climate change (Target 13.2)

The 2030 Agenda for Sustainable Development charts path to sustainable development more generally, and the guideposts are the 17 Sustainable Development Goals (SDGs). Accomplishing the SDGs will rely on advances in sustainable transport. Global progress in reducing greenhouse gas emissions cannot be realised without decisive action in sustainable transport, and countries cannot provide food security or healthcare without providing reliable and sustainable transport systems to underpin these advances. Young people cannot attend school, women cannot be assured opportunities for employment and empowerment, and people with disabilities and elderly people cannot maintain their independence and dignity without safe transport that is accessible itself and that enables access to all that people need. Personal security for all passengers is critical. Goals of biodiversity and ocean health also have significant intersections with the promotion of smart, sustainable transport practices across regions and across modes. In addition to these systemic connections, some SDGs are directly and indirectly connected to sustainable transport through targets and indicators, as illustrated in the figure on next page. The SDG on ensuring health and well-being includes a target addressing deaths and injuries from road crashes (3.6), and the SDG on inclusive, safe, resilient and sustainable cities include a target on expanding public transport (11.2).

Road transport of passengers and goods is a critical component of the United Nations' 2030 Global Sustainable Development Agenda, which seeks to “take the bold and transformative steps which are urgently needed to shift the world onto a sustainable and resilient path”. The use of buses and coaches as collective passenger transport are the most affordable, efficient, safe and environmentally friendly way to achieve sustainable mobility for all, at the fairest cost for society. Whether it is clean, green technology, innovations in buses and coaches, or reducing the environmental impact of road transport by cutting emissions, a commitment to sustainable and efficient transport by road is a key tenet of Busworld Foundation as it seeks to integrate the universal Sustainable Development Goals (SDGs) into every aspect of its practice.



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1.3 A Common Global Framework for Sustainable Transport

For more than half a century, most countries have experienced rapid urban growth and increased use of motor vehicles. This has led to urban sprawl and even higher demand for motorized travel with a range of environmental, social and economic consequences. In the coming decades, it is expected that approximately 90% of global population growth will occur in cities of developing countries. These cities are struggling to meet increasing demand for mobility and investment in transportation. Today, the development of sustainable transport including the delivery of accessible, cost effective and sustainable mobility represents a major challenge for countries and regions especially for landlocked developing countries (LLDCs), least developed countries (LDCs) and Small Island developing states (SIDSs). The international community is increasingly prioritising sustainable transport at multilateral level, considering that the requirements for safe, inclusive, resilient and sustainable transport should increasingly go hand in hand with more stringent requirements in terms of safety and security, reducing the impact on the environment and climate change, and improving energy efficiency. The achievement of sustainable transport systems would ensure greater connectivity with the world markets and expanded business opportunities.

In 2014 and 2015 several key UN Resolutions aiming at promoting international transport, tourism and transit corridors were adopted. The Addis Ababa Action Agenda in July 2015 recognised the critical role of Business and Public-Private Partnerships (PPPs) as a source of investments and as a driver of technological development and innovation. Transport has been explicitly reflected in the 2030 Agenda for Sustainable Development. Paris Climate Change Agreement has also created great opportunities and responsibilities for the transport sector. In its report titled 'Mobilising Sustainable Transport for Development' the United Nations Secretary General's High-Level Advisory Group on Sustainable Transport (HLAG-ST) has also acknowledged that access is at the heart of sustainable development. It has also emphasised the fact that accomplishing the SDGs will rely on advances in sustainable transport. The "Avoid-Shift-Improve" approach is increasingly accepted as a useful framework for taking action in support of sustainable transport. Implementation of UN resolutions relating to transport and tourism in every country of the world will empower Governments in policy enhancement, and businesses to explore, innovate, create and build opportunities for better mobility and growth.

1.4 Sustainable Transport at the Heart of New Urban Agenda

By 2050, the world's urban population is expected to reach 66% of the total global population. Africa and Asia together will make up nearly 90% of this increase. In developing countries, the demand for mobility for both people and goods is growing significantly every year, and safety in these countries is of particular concern. Information and Communications Technologies-enabled (ICTs) approaches for smart urban transportation have a vital role for achieving Sustainable Development Goal (SDG) targets relating to sustainable urban transport. Sustainable urban transport key drivers focus on demand, enabling policy environment and, in particular, promoting collective Public Transport-Orientated Development, besides financing and use of ICTs.

The bus transport system plays an important role in bridging disparities, in particular the connectivity between rural and urban areas. Bus transport is the cheapest form of public transport with large co-benefits – social, economic and environment. The 2030 Agenda for Sustainable Development, with 17 Sustainable Development Goals (SDGs) and 169 related targets at its core, represents a plan of action for people, planet and prosperity, and reflects national commitments to put the world on a more sustainable and resilient path. Through the adoption of this Agenda, member states have acknowledged the vital role of sustainable transport in achieving the SDGs. The goals of biodiversity and ocean health also have significant intersections with the promotion of smart and sustainable transport practices across regions and across modes. Sustainable transport means that is should be safe, affordable, accessible, efficient, resilient, low carbon and with minimum environmental impact. In addition to rising number of mega-cities, recent decades have witnessed a rise of polycentric metropolitan regions consisting of a number of connected large urban areas, which pose a new set of challenges in transport planning and development. Urbanization should take into account the entire population as a sizeable population. The first mile and last-mile connectivity which are mutually reinforcing to enhance rural-urban connectivity are extremely important. The first and last mile concepts interact because they enable goods and services to reach the poorest communities and facilitate movement of agricultural produce from farms to market. The Bangkok 2020 Declaration (2010-2020) adopted at the UNCRD led Intergovernmental 5th Regional EST Forum in Asia (2010, Thailand), aims to influence the decisions of governments and various transport stakeholders in the region over the decade (2010-2020) towards realization of safe, secure, affordable, efficient, people- and environment-friendly, and inclusive transport in rapidly urbanizing and modernizing Asia.

The New Urban Agenda (NUA) adopted at the Habitat III Conference in Quito 2016 has highlighted the critical role of transport in furthering sustainable urban development. It urges a “transformation in mobility policy” with a prominent role of collective door-to-door public transport, together with walking and cycling, as a crucial element of the integrated land use and transport planning. Both national and local governments have an important role to play in implementing various commitments, in partnership with businesses and international organizations, such as Busworld. The New Urban Agenda has rightly emphasized the urgency of the paradigm shift required, to cope with the widely predicted urban challenges the world will be facing in the coming years, through massive increase in accessible walking, cycling and, indeed, collective door-to-door public transport, infrastructure and services. NUA also highlights the need to decarbonize urban transport to make cities more resilient. The New Urban Agenda has further emphasized the need to take measures to improve road safety and integrate it into mobility and transport infrastructure planning and design, and at the same time promoting the implementation of the UN vehicle safety regulations.

1.5 Sustainable Urban Mobility for All

UN-Habitat’s Global Report on Human Settlements, titled Planning and Design for Sustainable Urban Mobility, provided guidance on developing sustainable urban transportation systems. The report outlined trends and conditions and reviewed a range of responses to urban transport challenges worldwide. The report has also analysed the relationship between urban form and mobility and called for a future with more compact and efficient cities. There is an important role for urban planning in developing smart and sustainable cities where non-motorised travel and collective door-to-door public transport are the preferred modes of transport. Success in this area is essential to create more equitable, healthy and productive urban living environments that benefit both people and the planet. The report also provides recommendations on how national, provincial and local governments and other stakeholders can develop more sustainable urban futures through improved planning and design of urban transport systems. There is also a need to improve the public image and acceptance of collective public transport systems. More needs to be done to increase reliability and efficiency of integrated public transport services, widely understood, including taxis, car sharing and long-distance coaches, and to make these services more integrated, secure and safe. Most trips involve a combination of several modes of transport. Thus, modal integration is stressed as a major component of any urban mobility strategy. Collective public transport in cities creates value for citizens, businesses, visitors and public authorities that far exceed the costs of its provision. Eco-mobility is one key to decrease cities' carbon footprint and to the successful implementation of the Paris Climate Agreement.

1.6 Need for Increasing the Use of Collective Passenger Road Transport

Promoting the use of collective passenger transport, in particular by buses and coaches, is the most affordable, efficient, safe and environmentally friendly way to achieve sustainable mobility for all, at the fairest cost for society. Buses offer several advantages to the transport systems. Buses can go everywhere in a city and "feed" rail/metro services and provide connectivity to the peri-urban and rural areas around the city. Buses are cheaper than other transport modes and infrastructure – both capital and ongoing costs per passenger kilometre. Buses will always be the mode that reaches every part of the city, in any scenario. Their capacity can be rapidly increased for modest capital input. Buses need to be put at the centre of policy and developed to full capacity, even if metro systems are implemented

1.7 Innovations in Public Road Transport to Revolutionize Business Models, Service Offer and Mobility Behaviors

App-based on-demand mobility solutions, electro-mobility, vehicle automation and Mobility-as-a-Service (MaaS), together with the new business models and practices, such as integrators' and aggregators' digital booking platforms, are key innovation breakthroughs, which are expected to revolutionize business models, service offer and indeed citizens' mobility behavior in the very near future.

The mass use of smartphones and apps across the globe both in developed and developing countries are the most visible part of the technology revolution iceberg. The impact of the smartphone-based app revolution is being felt in almost every industry: from communications and commerce, to banking and entertainment. Mobility, in general, and urban transport, in particular, are also experiencing their own revolution caused by the various mobility apps, which allow commuters/travelers to connect with services and drivers through smartphone apps by just pushing a button.

ICT innovations have also given rise to collaborative economy mobility models, making bike sharing and car-sharing systems much more viable, competitive and attractive. In terms of supply, ICT is helping to improve the efficiency of transport networks and coordination of different transport modes through passenger information systems, real-time traffic management centers, integrated electronic information, booking and ticketing systems, automated control systems allowing vehicles and infrastructure to communicate. A number of Mobility-as-a-Service (MaaS) schemes and services are also emerging across the globe. Recent years have seen an explosion in innovation in three categories of technology relevant to transport: power, vehicles, and operating systems.

Recently, a growing number of businesses have started working intensively on pilots for autonomous vehicles (AVs). By reducing the impact of human factor behind the wheel, autonomous vehicles are expected to contribute to cutting accidents by as much as 90 percent, saving thousands of lives. Among other things, autonomous driving could also increase the carrying capacity of roads because vehicles would be able to travel closer together and at higher speed.

Smart Urban Mobility through Prioritising Collective Public Transport, Commitment, Leadership and Public-Private Partnership

The 2030 Agenda spells out seventeen Sustainable Development Goals (SDGs) and it defines multiple targets, laying out a roadmap for economic, social and environmental policy development, transformation and a better future for all. Sustainable transport has been included in 7 of the 17 goals and is covered directly by 5 targets and indirectly by 7 targets. As part of the global transport narrative four possible goals are considered important. These are (i) Access for All (ii) Efficiency (iii) Safety and (iv) Climate Respect. A global tracking framework (GTF) is also being developed to measure progress towards the four goals, using country level indicators with differentiated pathways to realise goals for developed and developing countries.

Yet, prioritising the development of collective door-to-door public passenger transport, widely understood, involving both traditional and new private sector public service providers, such as buses, coaches, taxis, and intermediate public transport, can play a key role to achieve sustainable transport goals.

The latter should be given particular emphasis in transport policy and planning, with the objective to build an efficient and inclusive mobility chain, of which a 24-hour per day / 7 days per week accessible door-to-door public mobility chain is the backbone.

Importantly, setting a clear policy and business target to increase the use and modal share of collective public transport, in which private sector service providers play a key role, will facilitate the development of a pro-active public, financial, fiscal, legislative, market and operational environment, which will encourage service provision and thereby produce a shift in travelers' behavior. This will facilitate achieving an inclusive, efficient and sustainable mobility for all - citizens and visitors - at the lowest cost for society.

Reaching such extremely ambitious global objectives, as defined in both the 2030 Agenda for Sustainable Development and the Paris Climate Change Agreement, requires new approaches, in particular in terms of individual and collective commitments, leadership and cooperation at all levels – international, national, regional, local and public-private. It requires putting together all available resources, energies and wills in a genuine public-private partnership.

The Global Partnership for Sustainable Transport (GPST)[1], which could successfully play the role of a key global enabler to achieve transport-related SDGs and climate change objectives are also part of this mainstream global effort towards achieving sustainable transport.

Over the last few years, a number of individual and collective actors, organizations and stakeholders across the globe, including, recently, the UN Secretary Generals High Level Advisory Group on Sustainable Transport, have been working upon and making concrete recommendations for policy development and implementation to achieve sustainability in transport.

1.8 Together on the Road to Sustainable Mobility for All

Five years have passed since the global adoption of the Sustainable Development Goals (SDGs), on September 25, 2015, by the UN General Assembly. The 2030 Agenda outlines 17 crucial universal Sustainable Development Goals (SDGs) and it defines multiple targets.

UNCRD is now planning to develop a new roadmap for environmentally sustainable transport for member countries in Asia and the Pacific. The most relevant SDGs include, for example, (SDG 1) poverty alleviation by promoting sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all (SDG 8), building resilient infrastructure, and promoting inclusive and sustainable industrialisation and foster innovation (SDG 9), and reducing inequality within and among countries (SDG 10). SDG 3 on health includes a target on road safety, calling on the global community to cut road deaths by half by 2020. The 2030 Agenda also calls for making cities and human settlements inclusive, safe, resilient and sustainable (SDG 11).

Recognising that the SDGs require strong support from the private sector, the 2030 Agenda outlines a strategy that supports public-private partnerships. With its strong partnership network across the transport chain, Busworld seeks to engage private enterprise and acknowledges the need for collaboration, investment and alignment. Importantly, Busworld is well placed to work with its partners to establish a “business case” for the private road transport sector to engage with SDGs and contribute to the achievement of safe, inclusive, resilient and sustainable mobility for all.

[1] https://www.un.org/esa/ffd/wp-content/uploads/sites/2/2015/10/GPST-Concept-and-development-strategy.pdf

1.9 New approaches in urban transport

Various approaches have been pilot-tested to urban transport operations, including public mass transit systems. Keeping in view the needs of developing countries, the following elements are important in future urban transport operations:

- **Public transport systems[2].** These are needed to provide urban populations with safe, secure, accessible, rapid, efficient, and user-friendly transport, and to reduce pollution, congestion, and accidents. Important among these will be bus rapid transit systems.
- **Non-motorized transport.** Integrated urban transport solutions should make provision for non-motorized transport infrastructure together with pedestrian zones and walkways, segregated cycle paths, and bicycle parking and rental programs.
- **Integrated urban transport planning.** Urban transport plans should be integrated with urban land use plans to support more efficient approaches to planning urban expansion and redevelopment, limit trip lengths needed, make sustainable modes convenient for users, and optimize system integration.
- **Demand management.** In parallel with improving public transport and non-motorized transport, cities need to use demand management to limit congestion and improve traffic flows by reducing the attractiveness of private vehicle use in busy urban areas. Options range from relatively simple systems, such as charging for vehicle licenses and parking fees, to more advanced computerized road-pricing schemes.
- **Traffic management.** Traffic engineering[3] and traffic management systems[4] are needed to optimize traffic flows on the available urban transport infrastructure.
- **Stimulating technology development and manufacturing:** Enhancing ability to rapidly scale markets for new types of vehicles, fleet-driven services, zero-emission buses, and other digital enabling technologies opens a door for rapid economic development and job creation. ·
- **Stimulate the implementation of these new technologies by providing adequate financial strategies**

[2] Public transport is a system of transport, in contrast to private / individual transport, for passengers by group travel systems available for use by the general public, typically managed on a schedule, operated on established routes, and that charge a posted fee for each trip.

[3] The science of traffic engineering is that science that uses engineering techniques and traffic regulations in order to achieve safe and efficient movement of traffic on roadways.

[4] Traffic management systems are composed of a set of application and management tools to improve the overall traffic efficiency and safety of the transportation systems.

Chapter 2: Addressing Climate Change in Transport in Asia

Motorized transport emissions in Asia have become a significant contributor to the global problem of greenhouse gas (GHG) emissions that leads to climate change. In 2009, transport was responsible for 23% of global GHG emissions (23% in Asia, 14% globally) compared with 41% for energy. But by 2035 transport is expected to become the single largest GHG emitter accounting for 46% of global emissions, and by 2050 it is set to reach 80%. Emissions from transport are the fastest-growing source of carbon dioxide (CO_2) emissions, with the vast majority of projected increases expected to come from developing Asia. In 2006, Asia accounted for 19% of total worldwide transport sector–related CO_2 emissions. By 2030, the share of Asia in total worldwide transport sector–related CO_2 emissions will increase to 31%.

2.1 Mitigating climate change in transport

In view of the priority accorded internationally to the issue of climate change, there is an urgent need for developing effective, efficient solutions that can work on a large scale in the transport sector in developing Asia. A useful conceptual tool to guide this work at country and regional level is the avoid–shift–improve approach as suggested by the UN Secretary General’s High-level advisory group:

- **Avoid** means reducing the need to travel—for example by integrating land use and transport planning to create local clusters of economic activity that require less mobility; by changing how production is organized (e.g. doing more online); and by developing multimodal logistic chains to cut wasteful and unnecessary trips.
- **Shift** means changing to more energy efficient modes or routes—such as shifting passengers from private vehicles to public transport and non-motorized modes.
- **Improve** means using technologies that are more energy efficient including through improving vehicle standards, inspection and enforcement; developing improved vehicle technologies and fuels; and improving transport efficiency using information technology

ADB’s Sustainable Transport Initiative by reducing energy consumption and emissions through distance shortening aims at promoting business models capable of realizing the potential competitiveness of different modes—within the public sector, privately, or through public–private partnerships.

Need for mainstreaming climate adaptation measures into different transport operations which may inter alia include making climate adaptation adjustments to engineering specifications, alignments, and master planning; incorporating associated environmental measures; and adjusting maintenance and contract scheduling.

2.2 Adaptation to climate change in transport

One of the dimensions of climate change is that transport investments are vulnerable to the effects of climate change. Such effects include rises in sea-level, changes in permafrost conditions and locations, changes in precipitation, and increases in the frequency and intensity of storms, floods and droughts. These have consequences to the design, construction and alignment of roads and other transport infrastructure. In order to address these challenges, there is a need for developing improved analytical tools to systematically integrate adaptation measures into various transport operations.

2.3 Road safety and social sustainability

Out of an estimated 1.18 million deaths and millions of injuries globally each year due to road accidents, 60% occur in Asia. To have a more sustainable impact on road safety in developing Asian countries there is a need for providing effective solutions to the transport needs of the poor.

The burden of road accidents falls disproportionately on the poor. According to the World Health Organization, almost half of those who die in road traffic crashes are pedestrians, cyclists, or users of motorized two-wheelers, and this proportion is higher in poorer economies.

To have a more sustainable impact on road safety in developing countries there is a need for developing comprehensive road safety operations which should support both engineering and behavioral approaches to the safe design, construction, operation, and maintenance of road infrastructure; the use of intelligent transport systems for road safety; and the development of road safety management capacity, road safety performance measurement, and resource mobilization.

2.4 Strengthening social sustainability

Providing effective solutions to the transport needs of the poor by improving transport services and providing improved facilities such as pedestrian and bicycle lanes to make transport accessible and safe for all users and social groups including women and the elderly and using tariff and subsidy options to increase access for vulnerable groups.

The 2030 Agenda for Sustainable Development charts this kind of course. Through sustainable transport, we can make significant progress on the Sustainable Development Goals and the Paris Climate Agreement, improving the lives of billions of people around the world.

We are addressing here global trends, including urbanization, demographic shifts, and globalization, as well as technological progress in digital connectivity and propulsion solutions.

There is an urgent need for action to address the staggering social, environmental, and economic costs associated with ‘business as usual’: every year 1.24 million people die in road accidents and a further 3.5 million people die prematurely due to outdoor pollution, including from transport sources; 23% of energy-related greenhouse gas emissions in Asia come from transport; and road congestion is a tremendous burden on the economy, currently accounting for 0.7% of the GDP in the United States, 2% of GDP in Europe, 2–5% of GDP in Asia, and as high as 10% of GDP in some cities of emerging economies, including Beijing, São Paulo and Lima.

Sustainable transport presents enormous opportunities by saving hundreds of thousands of lives every year through improved road safety and reduced air pollution and reducing carbon emissions by 7 gigatonnes. The transformation to sustainable transport requires a redirection, rather than any substantial increase, in infrastructure expenditure and can be realised through an annual investment of around US$2 trillion, similar to the current 'business as usual' spending of US$1.4 to US$2.1 trillion. When considering full transport costs, including fuel, operational expenses, losses due to congestion, and vehicles, sustainable transport can deliver savings of US$70 trillion by 2050.

Technology promoting clean fuels and clean energy are of high priority: Promote sustainable transport technologies through outcome-oriented government investment and policies that encourage private sector investment and action through various incentive structures.

2.5 Urbanization and urban-rural integration

More than half of humanity – 3.5 billion people – lives in cities today. By 2030, almost 60 per cent of the world's population will live in urban areas. 95 per cent of urban expansion in the next decades will take place in the developing world. The world's cities occupy just 3 per cent of the Earth's land, but account for 60-80 per cent of energy consumption and 75 per cent of carbon emissions. Rapid urbanization is exerting pressure on the living environment and public health. But the high density of cities can bring efficiency gains and technological innovation while reducing resource and energy consumption

By 2050, the world's urban population is expected to have grown by 2.5 billion people, reaching 66% of the total global population. Africa and Asia together will make up nearly 90% of this increase until 2050, and, with this boom, economic mass will continue to shift from the mature economies toward the emerging markets. In 2015, there were 29 megacities of over 10 million people, and by 2030 there will be an additional 12 megacities, with ten of them in Africa and Asia. In addition, recent decades have seen the rise of polycentric metropolitan regions consisting of a number of connected large urban areas, which present a new set of challenges for transport planning.

Currently, in much of the world, urban growth is poorly planned or managed, and the result is often sprawl and inadequate transport and infrastructure. 'Informal' transport options—unregulated private operators running small to medium-capacity low-performance vehicles such as collective taxis and mini-buses—often fill the gaps, but on their own they cannot meet the needs of all people. Formal and informal transport both contribute to a host of challenges in cities, in terms of safety, personal security, congestion and pollution, disproportionately affecting the poor.

In many cities in developed and developing countries alike, congestion, pollution, shifting economic centres and demographic patterns present imminent threats to lives and livelihoods. The transport landscape in urban agglomerations is often highly inequitable, with poor and disabled people left with inadequate means to access the economic and social centres of the cities. The burden of climate change adds another layer of urgency and complexity to the problems decision makers must address in their quest to create sustainable cities.

Urbanization must be considered in the context of the entire global population, remembering that today, in some developing regions, the majority of the population is still residing in rural areas. Also, it is important to note that in some developed countries, urban centres, in fact, have diminishing populations and pockets of very low density. In both developing and developed countries, rural connectivity is an ongoing challenge, especially as economic and social activities and opportunities are often based in cities, towns and markets.

Chapter 3: Changing Course in Urban Transport: Low Emission Vehicles and Alternative Fuels

Low-emission vehicles are those that achieve reduced fuel consumption through innovative engine design, including technologies such as hybrid petrol vehicles, diesel, and electric engines. All vehicles, including two- and three-wheelers and larger passenger and freight vehicles, can include more efficient engine technologies and use alternative fuels. In terms of passenger vehicles, the current best generations worldwide of hybrid petrol vehicles have an emissions level of about 100 grams of carbon dioxide per kilometer (gCO_2 /km). (The Toyota Prius, which is a hybrid gasoline vehicle, emits 89 gCO_2 /km.) The small diesel vehicles are similar (the Volkswagen Polo Blue Motion emits 89 gCO_2 /km). The intention with technological improvements is to push hard to reduce these levels even further. Perhaps most important is moving the very promising technologies into the mass market.

In Asia, the key initial stage is to develop the range of technologies and fuels available for mass consumption. In India, for example, there are plans for hybrids to be made available, including the Honda hybrid Civic Sedan, and the Mahindra Industries hybrid SUV. TVS Motor Company and Bajaj Auto are developing a hybrid three-wheeler. The size and mix of vehicles using the road network are very important in terms of energy usage, emissions, and road space.

The smaller and lighter vehicles are much more efficient. This includes the small motorcar and two- and three-wheelers. The car market in India consists largely of small vehicles, but this is less so in the PRC, Malaysia, and elsewhere, where larger and heavier vehicles are preferred.

Diesel fuel is widely used in public bus transport because a **diesel** engine provides more torque than **petrol** engine. Some advantages of diesel include: Less Pollution – although diesel fuel is non-renewable, the exhaust contains less carbon dioxide and nitrous oxide, which contributes to smog and pollution in the environment.

Alternative fuels can also be used alongside emerging engine technologies. There are many possibilities, some of which are listed below.

- **Compressed natural gas (CNG):** A gaseous mixture of hydrocarbons with 80%–90% methane. CNG is colorless, odorless, non-toxic, highly flammable, and compressed to improve storage capability. Most CNG vehicles are retrofits, converted from gasoline and diesel vehicles. CNG contains less carbon than any other fossil fuel. In Delhi all buses are run on CNG for the last two decades.
- **Liquid petroleum gas (LPG):** A mixture of gases, liquefied by compression or refrigeration. The major drawback is limited supply—ruling out any mass conversion to LPG fuel. Buses in Jakarta are also powered by liquified natural gas (LNG). Asia’s fast-growing gas markets need a well-functioning LNG supply chain.

Use of LNG in **buses** is gaining momentum around the world. Europe, China and the United States have already started using LNG powered trucks for long-distance freight carriage. It is also an attractive option for commercial **buses** plying over long distances.

- **Methanol:** An alcohol. Most of the world's methanol is produced by a process that uses natural gas as a feedstock. It is possible to produce methanol from feedstocks, such as coal or biomass, or urban waste and refuse.
- **Ethanol:** Alcohol-based, but considerably cleaner, less toxic, and less corrosive than methanol. Ethanol also has a high volumetric energy content. It can be produced by the fermentation of sugar cane or corn. Ethanol is more expensive to produce than methanol and requires large harvests of crops and large amounts of energy for production. One-third of the 12 million cars in Brazil are ethanol powered. In India Scania is now gearing up to manufacture 55 buses for Maharashtra's Nagpur city. The city already hosts a pilot project of Scania bus which runs on biofuel (95% ethanol). For the bus to run smoothly the main challenge however is that there has to be a steady supply chain of high-quality ethanol.
- **Biodiesel:** Produced by reacting vegetable or animal fats with methanol or ethanol to produce a lower viscosity fuel that is similar in physical characteristics to diesel.
- **Hydrogen:** Potentially the cleanest fuel option. However, hydrogen suffers from two major problems: production and storage. The fuel is highly flammable and requires large storage capsules. Hydrogen is not a fossil fuel and is not found in significant quantities in nature. It therefore needs to be manufactured: the most common methods are electrolysis of water, reforming natural gas, or partial oxidation and steam reforming other fossil fuels. Significant investments are needed in infrastructure for delivery, storage, and dispensing of hydrogen if it is to be used as a vehicle fuel.

Hydrogen fuel is a great way to power public and private transport in London. The only emission is water vapor which means that no carbon dioxide or other air pollutants are released into the air.

- **Hydrogen Energy for Road Transport**

Presently, hydrogen-related technologies are reaching maturity for commercialization, and the costs are continuously falling due to signs of progress in both technologies and supply chains. The US Department of Energy (DOE) has pointed out that, from 2001 to 2011, the cost of a fuel cell electrolyzer fell by 80% (DOE 2015). Mid 2020, the European commission adopted its Hydrogen strategy, which is to catalyse the use of hydrogen as one of the main energy suppliers on the continent. Mainstream policy-making institutes and international organizations, such as the US DOE and the International Energy Agency (IEA) (2019), anticipate that hydrogen energy will reach cost parity with conventional energy sources in the long term. Therefore, several countries and regions have announced a roadmap for their hydrogen energy industries as well as their hydrogen energy infrastructure, preparing for the large-scale commercial application of hydrogen.

As an energy application in the transport sector, hydrogen has many intrinsic advantages as an energy carrier. First, its energy intensity is higher than that of gasoline: 5 kg of hydrogen carried onboard a sedan vehicle can sustain driving for up to 500 km. Second, refueling can take place as quickly as that of gasoline and diesel. These two advantages make it especially suitable for vehicles undertaking long-distance or heavy-duty trips, such as inter-city buses and trucks delivering cargo.

The People's Republic of China (PRC) has also started to pay attention to hydrogen energy at policy-making levels in recent years. At the local government level, several provinces, as well as municipalities have started developing hydrogen energy industrial parks and demonstration projects of hydrogen energy applications. They have already deployed and put into operation more than a thousand units of fuel cell buses and logistics vehicles in these cities as a demonstration and test bedding of the technologies (China Hydrogen Alliance 2018, 2019).

- **Electricity:** There is much potential for electricity-fueled vehicles as a niche part of the market. CO_2 emissions depend on the nature of the energy source used to produce the electricity.

41% of U.S. public transit buses use alternative fuels, hybrid technology. Public transit systems report that 16.7% of U.S. transit buses used compressed natural gas (CNG), liquefied natural gas (LNG) and blends. **Biodiesel** is used by 7.4% of public transit buses. Other alternative fuels, such as **propane** and hydrogen, account for 0.3%.

Chapter 4: Identifying solution by the public transport industry

In some parts of the world, the population is shrinking and aging, while, in other parts, it is growing rapidly and getting younger. For example, the median age in 2015 in Germany was 46.5 years while in India it was 27.3. Many German cities, especially in the eastern part of the country, have experienced significant population declines after reunification, posing the opposite transport challenges to those experienced in Indian cities where the population is growing every year.

Demographic trends at both ends of the spectrum have consequences for transport. Broadly speaking, issues of accessibility and proximity are crucial in particular for elderly people, while younger generations are driving trends including the “sharing economy” and other approaches dependent on smart phone connectivity. However, these trends vary according to the region and level of development, and all policy decisions must take account of the specific context.

4.1 Alternatives to diesel on interurban services and long-distance trips

* Bio-LNG (Liquefied Natural Gas) is suitable to be used over long distances due to its high energy content and density. Blended at 20% with biomethane, produced from organic or other waste material, it can improve the environmental performance of vehicles. In addition, 20% of biomethane share is also assumed as the reference target in the NGVA Roadmap 2030 concerning the development of natural gas vehicles in Europe.

* Biofuels: biodiesel (usually referred to as FAME, which is fossil fuel blended with 7% biofuel) or hydrotreated vegetable oils (HVO) blended at 30% with fossil fuels are the two biofuels. As HVO can be blended at a higher level then FAMA, it offers greater emission reduction potential.

* Hybrid diesel electric. These vehicles will run on diesel on interurban roads, but switch into electric driving mode in urban areas.

* Hydrogen & Fuel cells vehicles may play a role on the longer run if the cost of ownership, infrastructure provision and reliability is made affordable, for transport operators.

* Full electric: The full battery electrification of buses and coaches for long distance is unlikely to happen, due to autonomy reasons, which is related to the battery weight and energy storage capacity.

(Source: IRU-Coach of the Future)

4.2 Zero emission city buses

4.2.1 Types

While electric buses (or 'e-buses') come in different types, the name always refers to a motor road vehicle that is mostly emission free at the point of operation. Because they are battery-driven and have a lower environmental impact than an internal combustion engine bus, they are usually viewed as 'clean' and 'green', particularly when charged with electricity derived from renewable energy sources:

a. **Plug-in hybrid buses** (PHEVs) are hybrid electric vehicles that use rechargeable batteries or other energy storage devices that can be recharged by connecting them to an external electric power source. PHEVs share the characteristics of both a conventional hybrid electric vehicle, with an electric motor and an internal combustion engine (ICE) and an all-electric vehicle equipped with a plug or other device to connect to the electrical grid.

b. **Full battery electric buses** (BEVs) are all-electric or purely electric vehicles with an electric propulsion system that uses chemical energy stored in rechargeable battery packs. BEVs use electric motors and motor controllers for propulsion in place of internal combustion engines (ICEs). They have no internal combustion engine, fuel cell or fuel tank and derive all their power from their battery packs. Battery buses are charged statically using mechanical and electrical equipment.

c. **Battery trolleybuses: also referred to as dual-mode trolleybuses (China) or hybrid trolleybuses (Germany).**

These are bus-type vehicles propelled by an electric motor, drawing power from overhead wires via connecting poles called trolleys. Power is supplied either from a central power source that is not onboard the vehicle or via on-board rechargeable batteries. This enables the vehicles to run electrically while independent of the overhead wires for part of their route while maintaining full operational capability. Battery trolleybuses are charged dynamically using the existing trolleybus catenary, or in when static with a device for connecting to the electrical grid.

d. **Hydrogen-fuel cell buses :** A fuel cell bus is a bus that uses a hydrogen fuel cell as its power source for electrically driven wheels, sometimes augmented in a hybrid fashion with batteries or a supercapacitor. A tank with hydrogen under high pressure in fuel cell buses replaces the battery in standard electric buses, as energy storage.

4.2.2 World Market

The last decade has seen progressive and positive developments in e-bus technology, led mainly by China, closely followed by Europe and the USA.

The successful deployment of the first full battery e-buses during the Olympic Games in Beijing in 2008, followed by the launch of a 12m full-battery electric bus with a range of

250-300 km in 2010, opened up the e-bus market for Chinese manufacturers. American and European bus manufactures rapidly developed their own e-bus models, which were initially tested in small-scale pilots of one or two vehicles. Subsequently, the operations matured into larger schemes and shifted entire bus lines from ICEs to electrical power. Meanwhile, over 500 cities have placed large orders for e-buses.

At the same time, the high number of products launched by e-bus manufacturers, and the appearance of new manufacturers, are indicative of the increasing level of competition within the sector. Public transport operators are beginning to focus more on the long-term than the upfront costs, thanks to funding backup from governments and venture capitalists. With China, the USA and Europe as frontrunners, many other pioneering countries are joining the transition to the electrification of the bus systems.

The global market for electric buses has declined since a spike in sales in 2016. In 2019, new electric bus registrations numbered around 75, 000, down 20% from 93, 000 units in 2018. The explanation lies in the decline of Chinese subsidies for the production and procurement of electric buses. Today, there are about 400,000 electric buses worldwide, of which 98% are deployed in China[5]. Still according to Bloomberg New Energy Finance, at the end of 2017 there were 3 million city buses in operation worldwide; of these, 385,000 belong to the category of electric bus. The incidence on the global fleet is therefore 13 per cent.

Also **India** (70,000 buses sold in 2017) is a market with big potential, when even a small part of the orders will be electric. By 2025, the research company Interact Analysis forecasts that India will account for more than 10% of the total annual demand for electric buses globally, which is more than Europe and North America combined.

Vehicle emission standards for new vehicles have been adopted by a number of countries globally, and there is marked variation. The intention is to gradually make the new vehicle fleet more efficient in terms of CO_2 emissions. Motor manufacturers can operate within defined market boundaries, and wider societal goals can be achieved. For example, the PRC moved from a 2002 average of 210 gCO_2 /km to below 170 gCO_2 /km by 2009; the European Union from 168 gCO_2 /km to 130 g/CO_2 km in 2015 and 95 gCO_2 /km by 2020 (via the EU Voluntary Car Agreement, through which the European Automobile Manufacturers Association and the European Commission agreed to limit the amount of CO_2 emitted by European cars). Japan is slightly more progressive, targeting below 130 gCO_2 /km by 2015. US standards are much less stringent, targeting just 170 gCO_2 /km by 2020. There are no current agreements in India or Southeast Asia.

Greater use of public transportation means less cars on the road and a cleaner environment. The public transportation industry making use of alternative fuel and incorporating green, sustainable practices lead to sustainability.

[5] Source: The Electric Vehicle Outlook by Bloomberg New Energy Finance.

Promotion of EV bus manufacturing in India

For mitigating the environmental impact there is a need for migrating to EV vehicles as well as gradually decarbonisation of the energy production. Efficient and adequate public transport based on E-Buses can definitely reduce the necessity or the usage of personal transport.

FAME-II programme with an outlay of Rs 100,000 million is incentivizing procurement of 7,000 buses. The programme focuses on shared mobility as buses and three wheelers get 70% of demand incentives. Under this programme, 5595 electric buses have already been sanctioned to 64 cities/state government. NITI Aayog has prepared MCA for procurement of e-buses on OpEx basis. Local authorities are exempt from GST for hiring of electric buses.

In addition to this States are also promoting the e-buses in their State Road Transport Undertakings. Some examples are:

- Andhra Pradesh: 100% of State's bus fleet into electric by 2029
- Assam to introduce 500 electric buses
- Delhi has declared that 50% of all new buses will be electric
- Gujarat has target of 1500 e-buses on road by 2022, plus development of additional 25 bus depots on PPP mode
- Kerala has targeted transition of entire 6000+ buses to EV by 2025
- Madhya Pradesh has targeted 100% bus fleet conversion to EV by 2028
- Maharashtra has declared additional subsidy of INR 10 Lakh on e-bus
- In Punjab Private Bus operators to be offered 100% waiver on Permit Fee & Motor Vehicle Tax
- In Telangana, 100% e-buses by 2030 for intra-city, intercity and interstate transport
- Tamil Nadu, around 1,000 EV buses to be introduced every year

NITI Aayog has come up with a scheme for battery cell manufacturing. It is in the process of being finalized. India has already started battery packaging, which constitutes nearly 30–40% of the total value.

Currently, there are only limited OEMs making EV buses – Tata Motors, Ashok Leyland, BYD, JBM, PMI Photon, Eicher. FAME II has outlined ~ USD 143 M for developing the charging infrastructure in the country. Indian Government has already approved the installation of 2,636 EV Charging stations in 62 cities in India. This would make at least one charging station available on grid of 4Km X 4Km grid.

- EESL will set up 2000 Charging stations in 2020-21
- OEMs are partnering to develop the charging infra in India
- Battery swapping facilities are launched by State-run Public-sector company
- Two-wheelers and three-wheelers can be charged at home or through new-age charging models like battery swapping. We have recently seen Indian Oil setting up battery swapping stations at their petrol pumps.

E-bus would be charged at the depot and these would be set up by the operators. So, essentially the charging landscape in India would be different from the western countries, where cars are the dominant mode of transport. So, we are on right track.

FAME II has allocation of Rs.10,000 million for charging infrastructure, and 2,636 charging stations for cities have already been allocated. The process of setting up of charging infrastructure on highways has started.

The public transportation industry is doing its part to help the environment. Every year, 37 million metric tons of carbon emissions and 4.2 billion gallons of gasoline are saved due to use of public transportation in the U.S.

American Public Transportation Association's research shows that 41.3% of U.S. public transportation buses were using alternative fuels or hybrid technology as of January 1, 2014. APTA statistics for 2014 show that 16.9% of public transit buses were hybrid electric. Coming in a close second, public transit systems report that 16.7% of U.S. transit buses used compressed natural gas (CNG), liquefied natural gas (LNG) and blends. Biodiesel is used by 7.4% of public transit buses. Other alternative fuels, such as propane and hydrogen, accounted for 0.3%.

4.3 Alternative energy sources for transportation:

For urban transportation, the main alternative and transitional energy sources are electricity, biofuels (e.g. vegetable oil and biodiesel), other gaseous fuels (natural gas, hydrogen, and LPG), alcohols (methanol and ethanol), and ethers

Alternative and transitional energy sources are derived from sources other than diesel and gasoline. For urban transportation, the main alternative and transitional energy sources are electricity, biofuels (e.g. vegetable oil and biodiesel), other gaseous fuels (natural gas, hydrogen, and LPG), alcohols (methanol and ethanol), and ethers (Fig. 1). Since the world energy crisis in the 1970s, alternative and transitional energy sources have received much attention. Among these, the use of natural gas in forms such as compressed natural gas (CNG) and LPG has increased rapidly over the past decades. Nowadays, there are more than 11.3 million natural gas-fueled vehicles on the road and 16,500 natural gas refueling stations worldwide. Natural gas is widely used because it is available in large quantities, relatively cheap, and has a well-developed distribution infrastructure. However, as its potential to reduce emissions is limited, it can only be adopted as a transitional energy source. Most current studies focus on electricity and biofuels, which may become the main long-term sustainable energy sources for urban transportation. Regarding the application of hydrogen, alcohols, and ethers, the new trend is to use them in fuel-cell vehicles instead of as primary fuels or to use them in combination with fossil fuels

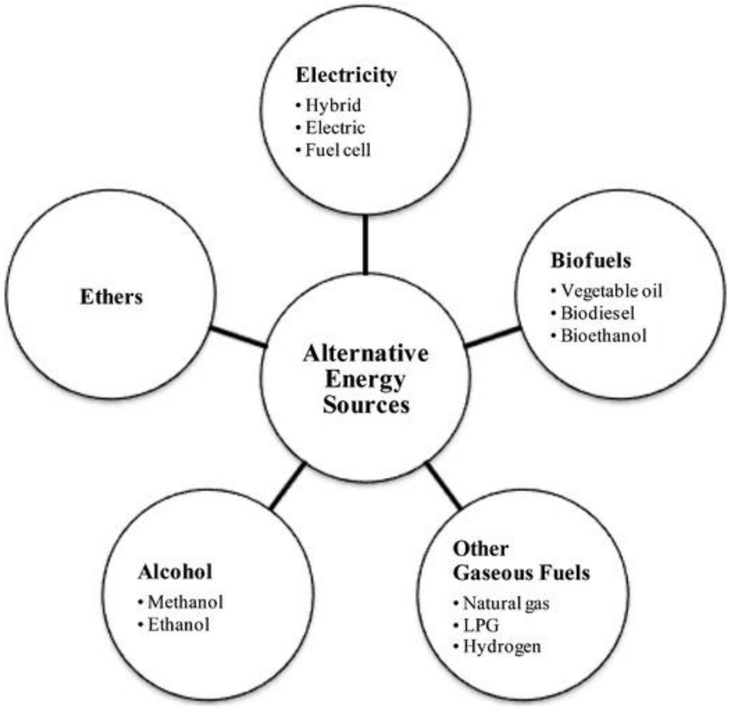


Figure 5: Type of alternative and transitional energy sources in urban transport

Public transport contributes approximately 25% of all energy related CO_2 emissions worldwide. Electric public transport is a super solution that could reduce 250 million tones of carbon emissions by 2030 and it has a lot more benefits.

4.4 Digital connectivity

The digital revolution transforming all aspects of life will have a major impact on mobility and transport, in both demand and supply. In terms of demand, information and communication technology (ICT) is enabling telecommuting, and video- and audio-conferencing can replace longer-distance travel. ICT innovations have also given rise to the sharing economy, making bike sharing, car sharing and transport on demand systems more viable and attractive.

In terms of supply, ICT improves the efficiency of transport networks through passenger information systems, real-time traffic management centres, integrated electronic ticketing systems, automated control systems allowing vehicles and track side or roadside equipment to communicate, and others. Many of these developments enhance the performance and attractiveness of public transport for consumers. In freight transport, ICT facilitates the implementation of intermodal solutions, as precise tracking systems ease coordination and the development of smart hubs. ICT also facilitates load optimization, whether of passengers or freight, and autonomous vehicles are showing promise. The mere presence of ICT-driven solutions does not mean that the old problems will vanish, however, and any roll-out of new technologies must be accompanied by comprehensive awareness-raising efforts and policy frameworks.

4.5 Development of greener, more efficient propulsion technology

As the international community confronts the climate crisis, and cities around the world face unprecedented levels of pollution, there are signs of a widespread shift—slow though it may be—away from a fossil fuel-based transport system. There are vastly different approaches and rates of uptake in different countries and regions, but as the Paris Climate Agreement shows, the world agrees that action must be taken.

This fundamental change will accompany a parallel global energy revolution. The question is not whether the transport and energy sectors will transform, but rather when and how.

Congestion and pollution—with accompanying twin health crises of traffic fatalities and health impacts of poor air quality—together with the climate imperative, are major drivers toward clean, green and smart transport technology. Effective technological innovation always needs to be linked to sustainable transport policies, because, as the Chairman of Ford Motor Company said, “a green traffic jam is still a traffic jam.” Alongside new technologies, it is also vital that existing technologies, for example those improving fuel economy in cars, are more fully utilized across the globe.

4.6 Technological Innovation and Vehicle Efficiency

Technological and other policy responses including the use of the best available technology can help increasing the efficiency of motorized vehicles. This implies that the use of carbon-based fuels should be substantially reduced, and cleaner low-carbon fuels should replace them for all forms of motorized transport (freight and passenger). The amount of CO_2 produced by motorized vehicles is directly related to the amount of fuel used, and there is considerable potential for reductions. However, it should be remembered that efficiency gains must be set against the growth in traffic, as this often outweighs those gains.

It is important to note that there is a substantial potential for technological ‘leapfrogging’. There is no reason why cities in developing countries have to follow the same high-motorization (and high-pollution) pathway as that followed in developed countries. Rapid urbanization in many developing countries thus presents an opportunity to invest in the low-carbon city transport system of the future. However, this cannot be undertaken without substantial financial support from the developed countries. This means that effective mechanisms need to be established, such as the fuel security credits being tested by the Asian Development Bank, or initiatives under the clean development mechanism of the Kyoto Protocol.

4.7 Standards of fuels used and emissions from vehicles

The emission of pollutants from motorized vehicles is related to three main factors: the quality of the fuel, the fuel efficiency of the vehicle stock and the capture of pollutants before they escape from the vehicle.

Considerable progress is being made in improving the quality of fuel used and the efficiency of the conventional petrol and diesel internal combustion engine, so that the typical car is now some 35 per cent more efficient than it was ten years ago. This improvement can be directly translated into reductions in CO2 emissions. The EU has introduced legislation (2009) for a reduction of the green-house gas intensity of fuels by up to 10 per cent by 2020 – a ‘low carbon fuel standard’. This will be achieved through the greater use of renewable energy in electric vehicles, and the use of biomass sources, such as bioethanol that is already mixed with fuel (5 per cent). Even though diesel vehicles produce less CO2 per unit of distance travelled, their increasing dominance in the vehicle fleet (both passenger and freight) has been negated by the greater distances travelled. Diesel vehicles also tend to have larger emissions of other pollutants, such as nitrogen oxides and particulate matter. As a result, the WHO has recently stated that diesel exhaust causes cancer, and has called for tighter emission standards, comparing the risk of exhaust to second-hand cigarette smoke. In India, the fuel quality standards for transport fuels are legislated under the environmental Protection Act (which follows the EU specifications). New specifications have been introduced in two phases, first applied in 13 major cities and then followed by nationwide implementation. India has used unleaded petrol nationwide since 2000. Reductions in the sulphur levels in diesel have major effects on emissions, as many developing countries have very high sulphur levels in diesel fuels. Reducing sulphur to very low levels also reduces the emissions of particulate matter, and it enables emission control technologies that provide even greater emission reductions (i.e. diesel oxidation catalysts and diesel particulate filters). For petrol vehicles, low sulphur levels in fuel improve the performance of catalytic converter systems that are standard in developed countries. Low sulphur levels are now being introduced in most developing countries as well, through the importation of new and second-hand cars. Governments are increasingly looking towards vehicle manufacturers to improve the fuel efficiency of the vehicle stock. Many governments are now setting more challenging mandatory targets for fuel efficiency in new vehicles, and this single action will substantially reduce CO2 and other emissions from the transport sector. The EU tried, unsuccessfully, to introduce voluntary agreements with the vehicle manufacturers during the last decade. It is only recently (2009) that mandatory targets have been set. However, the fact that good progress has already been made towards these targets may suggest that the targets are not tough enough.

There is evidence to show a clear downward trend in the emissions of CO2 from new vehicles and the fleet-wide mandatory targets set by the EU will be a benchmark for other manufacturers. Many pollutants can be filtered out through the use of catalytic converters, particulate traps and other technologies, although this means that additional costs are imposed on vehicle owners. It is, however, also important to ensure that the filters are working effectively, and this again relates to regular maintenance and testing of vehicles. Catalytic converters do not work when engines are cold, and so for many short journeys the pollutants are not being filtered out. Regulations in Europe have gradually been tightened up so that emissions levels for all vehicles (including freight vehicles) conform to EU standards. These standards are also being adopted elsewhere, for example in Russia and China. The US and Japan have their own emissions standards that have been tougher than those in the EU until 2000, but all three have since followed essentially the same path and are converging towards zero emissions for all pollutants. Due to the fact that the emission standards only apply to new vehicles, it takes a considerable time before their full benefits are realized, as existing older vehicles have to be scrapped and replaced by new vehicles.

4.8 Alternative fuels

In order to reduce the dependence on oil – and to reduce the emissions of greenhouse gases and other pollutants – there has been much debate over the introduction of alternative fuels in the transport sector. However, while searching for alternatives, it is important to keep in mind the fact that both petrol and diesel have very high energy densities, and that there have already been substantial investments in support infrastructure in most countries (e.g. fuel stations). Thus, alternatives need to have a high energy output and they must be produced cleanly and cheaply, and in sufficient quantities. In the near future, it is unlikely that any alternative fuel can replace the established oil-based sources of fuel, as they cannot be produced (or distributed) in the quantities required. This means that all alternative fuels are likely to be niche markets. However, these may in turn develop to mass-market options in the longer term. In situations where there is less established supporting infrastructure (e.g. in developing countries), the introduction of new fuels may happen earlier. This provides an opportunity to initiate new solutions to urban motorization in developing countries. This is already evident in some countries through the use of BRT and electric vehicles (including e-bikes).

In terms of policy, the EU seeks to halve the use of conventionally fuelled cars by 2030, to phase such cars out of cities by 2050, and to achieve carbon-free goods movement in cities by 2030. The EU believes that technological innovation will play a major role in this process, combined with regulations and standards being set by individual governments, demand management, road pricing and local city-level controls.

The public discussion related to alternative fuels started with a focus on greater efficiency within existing internal combustion engines. Efficiency levels have improved substantially, and a further halving of CO2 emissions is expected over the next ten years. Public debate has since moved onto biofuels and hydrogen. However, the potential of biofuels has been restricted by the conflicts arising from increasing food prices, as increasing production of energy crops has led to reduced areas of agricultural land producing food crops. The production of liquid fuels from sugar, biomass and cellulose also requires huge amounts of water. Likewise, as stated above, the potential of hydrogen as a clean fuel has been questioned because of the energy required in its production (often from carbon products, such as oil or coal), and because of issues related to the storage and distribution of the hydrogen.

More recent the electric vehicle has emerged as a more suitable alternative for urban transport. Such vehicles include hybrid electric vehicles, plugin hybrid electric vehicles and other electric vehicles (including battery-driven vehicles). Increased use of such vehicles would solve many of the local pollution problems. However, the energy still has to be generated (often from coal), and there are issues relating to the recharging infrastructure, the use of materials and the need for a lifecycle approach to energy use and emissions. The most positive developments have come from hybrid vehicles that combine conventional internal combustion engine with electric vehicle technology, as this allows both electric power at low speeds and a combination of internal combustion engine and electric power at higher speeds. In such hybrid vehicles, the conventional engine is supported by a battery that can be recharged while the vehicle is being used. Greenhouse gases and other pollutants are still being emitted, but these vehicles provide a direct substitute for the conventional car, but use only about 60 per cent of the fuel. Over the lifetime of the car it is likely that there are cost savings to the user, as the higher purchase prices are compensated for by lower fuel costs.

China has introduced a series of policies aiming to facilitate electric vehicle industrialization and commercialization, including pilot projects, standard announcements and purchase subsidies. In the industrial sector, a group of car manufacturers has announced mass production plans for electric vehicles. In some cities, electric vehicles are beginning to make a significant impact in terms of their share of public transport and public service vehicle fleets. This includes delivery vehicles, buses and other services (e.g. taxis). In June 2010, six cities were chosen to implement electric vehicle purchase subsidies with a maximum of US$ 9000 per vehicle in the private car market. One of these ‘electric’ transport cities is Hangzhou, where a variety of measures have been combined to achieve an innovative and environmentally beneficial transport pathway.

Although, worldwide, most attention has been given to technological innovation for the private car, there is also considerable potential within cities to use electric power and hybrid technologies for public and freight transport. London, UK, for example, had more than 300 hybrid buses in operation by December 2012, and similar initiatives are currently underway in Latin America.

Despite the clear intentions to reduce key emissions from vehicles, in practice it will take 10–15 years to work its way through the entire vehicle stock in developed countries. In developing countries, with their considerably older vehicle stock it will take even longer.

Add-on technology (principally the catalytic converter), cleaner fuels and more efficient and lighter vehicles have helped reduce the levels of pollutants from petrol engine vehicles by 80 per cent. There are, however, questions about whether the technology is working efficiently and the rate of change in the existing vehicle fleet, particularly in those cities with the most rapid increase in levels of car ownership. Furthermore, there are still concerns over whether the same levels of air quality improvement can be achieved in diesel vehicles. And, the problem of particulates is still present as this results from fuels (diesel), from tyres and from other sources, and this is much harder to control (and is a particular problem for freight trucks in urban areas). The belief that add-on technology can 'solve' the air quality issue is too simple. As noted above, there are important limitations relating to whether the catalytic converters are working, whether diesel emissions can be controlled effectively, the time taken for all vehicles to be fitted, and the slow switch to alternative fuels. When set against the growth in car ownership and use, the catalytic converter really only gives a maximum of ten years 'breathing space' before pollution levels start to rise again. In the US, for example, the catalytic converter has been compulsory since 1979, and the full benefits have already worked their way into the entire car fleet. The CO2 problem has not been addressed, as reduction in fuel use is the only means to reduce such emissions.

4.9 Zero Emission Buses

A zero-emission bus uses electricity to power a battery, and a number of companies are manufacturing zero emission buses that operate without overhead wires. This means no gasoline, no dirty oil changes, no internal combustion engine, no dirty exhaust. Some cities are also investing in hydrogen fuel cell buses.

Zero-emission buses (ZEBs) are considered a vital element in the transition to a more sustainable urban transport system. Both battery-electric and hydrogen fuel cell buses do however face significant barriers to large-scale implementation. These barriers, e.g. high investment costs and limited driving range, are generally regarded as exogenous technological barriers which are beyond the sphere of influence of actors in the public transport sector. For this there is a need to look at the role of institutions in public bus transport. Studies reveal that various regulative, normative, and cognitive institutions discourage the use of zero-emission buses in public transport. To increase the chances for these buses, there is a need for institutional innovations.

Zero-emission buses also face other barriers to implementation than range and costs alone. The transition is also held back by regulative, normative and cognitive institutions. Extending public transport concessions improves the competitiveness of electric buses. New business models could allow third parties to invest in recharging infrastructure.

4.10 Tackling urban air quality improvement with zero emission buses

Urban buses account for approximately 25% of the black carbon emitted by the transportation sector. Urban bus activity is predicted to increase by nearly 50% by 2030; this will translate into an estimated additional 26,000 tons of black carbon

UN Environment, in collaboration with partners is providing direct support to twenty major cities in Asia, Latin America and Africa to prepare roadmaps for low emission public transport, including the introduction of electric buses.

UN Environment seeks to address the significant emissions and public health burden of urban bus fleets by supporting soot-free engine technologies, including electric engines. This will impact a combined 234 million people, preventing approximately 3,700 premature deaths and as much as 6.6 MMT CO2e (GWP-20) by 2030 (or 1.7 MMT CO2e GWP-100).

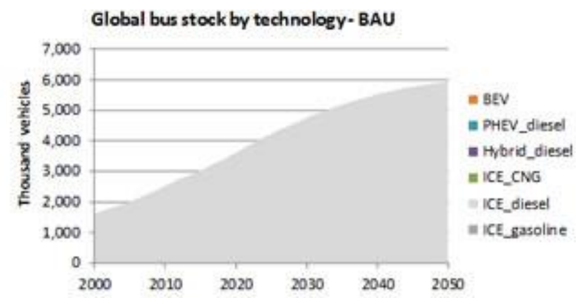
Together with the International Council on Clean Transportation (ICCT) and regional partners, UN Environment provides technical and policy support **to identify barriers**, undertake activities that can remove such barriers, and support the subsequent design and adoption of a public commitment to cleaner buses.

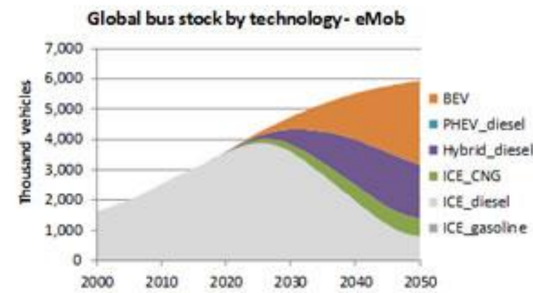
The dedicated strategy consists of the following elements:

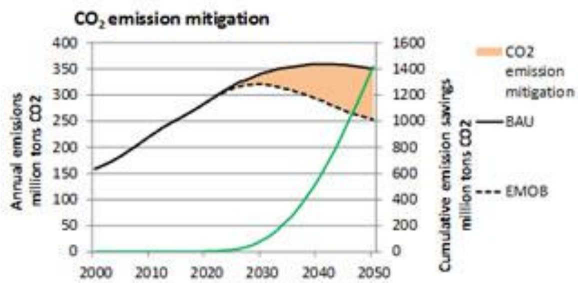
- Inform, motivate, and secure a public commitment from city officials to shift to soot-free urban bus fleets;
- Provide implementation support;
- Establish an industry partnership with engine manufacturers and suppliers of commercially available soot-free engines, including electric versions;
- Develop an urban bus fleet database; and
- Report back to the Heavy-Duty Diesel Initiative of the Climate and Clean Air Coalition on opportunities to expand the deployment of soot-free engines.

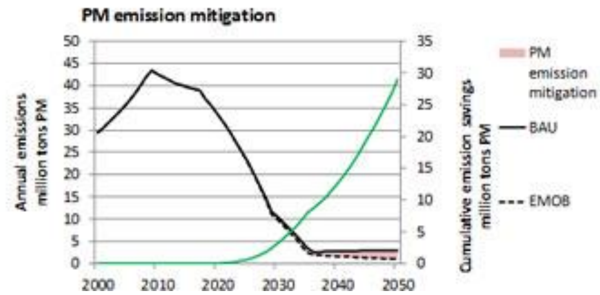
UN Environment has developed the eMob Calculator for ***estimating costs and benefits of a large scale deployment of electric*** buses, which enables the user to assess the potential of electric and other low emission buses (such as Euro 6 and CNG buses) to reduce energy use, CO_2 and air pollutant emissions as well as costs until the year 2050. The tool can be used to perform cost-benefit analysis on a national as well a city

An assessment of a business as usual scenario as well as an eMob scenario for the global heavy duty bus fleet indicates that a profound shift to zero and low emission battery electric, hybrid and CNG buses could save approximately 1.4 billion tons of CO_2 and almost 30 million tons of particulate matter between now and 2050.









4.11 Charging Infrastructure for Buses

The dynamics of **Charging infrastructure for electric buses** differ from other vehicle segments like **electric** 2W, 3W and cars. There are two major parts of **charging infrastructure**: **Charging** Solution and Power **Infrastructure**.

For public transport even on the street, electrification seems the obvious alternative to keep pace with urban growth and to care for the city environment at the same time, using full electric or electric hybrid buses. With the right charging technology, the advantages of electrified buses can be utilized: less energy consumption in comparison to buses with combustion engines, use of renewable energy, less noise, lower particle emissions, less CO_2, lower lifecycle costs, and reliable service.

Good solutions for e-buses make charging more efficient and affordable, and the use of renewables ensures no local emissions such as CO_2 or noise are produced.

Siemens eBus charging infrastructure has (a) Off-board Top-down-Pantograph (b) On-board Bottom-up-Pantograph and (c) Charging via connector

Siemens technology portfolio comprises fast charging solutions from 150 kW to 600 kW charging power as offboard charging solution as well as 60 kW to120 kW as onboard charging solution for opportunity charging on the route. There are plug-in charging solutions with 30 kW to 150 kW which are most suitable for depots. For depots the company experts compile tailored concepts in consideration of local grid conditions and energy cost aspects. On demand an active charging and energy management system can be integrated.

Good charging systems for e-buses provide several Community benefits:

- Perfect and versatile response to the growing demand for sustainable traffic solutions
- Local emission-free, low noise, reliable
- Can use energy from renewable sources
- No compromise on operational availability, transport capacity and passenger comfort

4.12 Challenges of E Mobility Specifically w.r.t. Buses

Technical Challenges	Potential
• Vehicle range • Vehicle cost • Battery pack replacement cost • Battery pack life • Charging	• High Energy Density Batteries • Improvement in Efficiency • Reducing Batteries cost • Integration and optimization, of EV aggregates • Longer Battery Life. New Chemistries for Cathode and Anode. Better Thermal Management • Higher Durability and Reliability of Various components and systems

Battery Sizing

Traffic, Weather and AC usage has a very significant influence on the energy consumption and thereby Range and influence on Battery sizing

- AC consumes almost 26% of the Battery Capacity Traction Motor, 63%
- Electrical loads, 3%
- Aux Motor, 8%

RANGE OF BATTERIES

E-Buses can run on all routes and get charged during breaks. Generally, the authorities are not comfortable with opportunity charging and want only one charging in night. Thereby necessitating the bigger battery and hence cost.

WAY Forward

Commercial Levers	Technical Levers
• Cost Optimisation • Aggressive localisation. • Shift from Built to Print to FSS suppliers • Invest in R&D and System • Design, testing and validation capability	• Improve Energy Efficiency • Optimisation of system and components • Innovative strategies
Optimisation of Battery Size • Based on the Duty cycle and Routes • Tradeoff between Life cycle and Initial Investment • Opportunity Charging	**COVID Compliant** • Individual Seat Layout • Shift to Positive Pressure Ventilation /improved Ventilation • Non-AC Buses may be adopted

4.13 COVID-19 and “New Normal”- Need for New and Green Technology for Public Transport

In the wake of the coronavirus disease (COVID-19) pandemic Public transport has to adapt a “new normal “and adopt technologies that will render it greener and more resilient to future disasters.

There has been profound impact of pandemic on transport, as swift lockdowns forced millions this year to work from home overnight, schools to shift to e-learning, and consumers to flock to online shopping and food delivery.

While public transit may have been previously perceived as a mostly green, efficient, and affordable mode of travel, initial trends in cities that have re-opened have indicated that public transit is still considered to be relatively unsafe and is not bouncing back as quickly as the use of private vehicles, cycling, and walking.

According to Bambang Susantono, ADB Vice-President for Knowledge Management and Sustainable Development. “The two key challenges ahead are addressing capacity on public transport to maintain safe distancing requirements, and how best to regain public confidence to return to public transport,” “In the short term, more effort is needed to reassure public transport users of safety and demonstrate clean and safe public transport. In the longer term, technological advances, big data, artificial intelligence, digitalization, automation, renewables and electric power can potentially offer fresh innovations to tackle changing needs, giving rise to smarter cities."

While drastic lockdown measures around the world have brought world economies to their knees, satellites have recorded data on how the concentrations of CO_2 and air pollutants have fallen drastically, bringing clear blue skies to many cities.

But as cities have reopened, traffic levels have increased. For example, Beijing traffic levels, by early April 2020, exceeded the same period in 2019. If this trend is seen on a wide scale, it could set back decades of effort in promoting sustainable development and more efficient means of urban mobility.

There is only a short window of opportunity for cities to promote the adoption of low-carbon alternatives to lock-in the improved air quality conditions gained during the peak of the pandemic lockdown. Public transport can play an important role through more active promotion of clean vehicles, provision of quality travel alternatives in public transport, and a better environment for non-motorized modes such as walking and cycling to enhance overall health and wellbeing.

The confidence of passengers on public transport should be restored through protective measures such as cleaning, thermal scanning, tracking and face covering. Further study to explore how protective and preventive measures can be stepped up to allow relaxation of safe distancing requirements would help mitigate capacity challenges. A possible future trend may be consolidation of services and rationalization of routes to better serve the emerging travel demand patterns and practices.

As countries enter the "recovery" phase, further preventive and precautionary operating measures and advanced technology should be implemented to enable contactless processes and facilitate an agile response. Demand management measures can facilitate crowd control in public transport systems and airports. As a complementary measure, non-motorized transport capacity could be expanded to absorb spillover demand from public transport.

Since mass public transport is the lifeblood of most economies, government policies and financial support are essential during this period, to enable public transport operators to stay viable and continue to support the movement of passengers and goods in a sustainable way.

Behavioral trends linked to COVID-19 require a review of the short-term viability of passenger transport and operational performance to meet changing demand for public transit systems. "Regardless of the COVID-19 pandemic it is clear that developing Asia will continue to have a large need for additional transport infrastructure and services," the report concludes. "It would take several years before the projects currently in the pipeline would be operational and much can happen during these years."

Chapter 5: Key barriers for adoption of Electric Buses

Electric buses (e-buses) can help cities address air quality issues and reduce greenhouse gas emissions (along with a clean grid). The transition to e-buses, however, has been subject to growing pains as industries and governments alike struggle to nurture the nascent e-bus marketplace into maturity. A study by WRI has identified some of the largest and most common barriers to e-bus adoption. Cities must fully understand the barriers to electric bus adoption to act swiftly and decisively to surmount these obstacles.

WRI has undertaken a study of 16 case studies based on which their report on the subject provides a matrix of barriers facing e-bus adoption. Barriers are categorized by (1) three major elements of the e-bus trade space and (2) three general barriers to clean energy innovation. Table below presents this barriers matrix. From this matrix, WRI report distills six key barriers facing transit agencies trying to adopt e-buses. These six key barriers are organized into the three general categories identified as **technological, financial, and institutional barriers**. These represent issues that transcend different elements within the e-bus trade space. The available case studies suggest that these barriers will likely be faced by many transit agencies and are potentially debilitating issues that must be resolved for e-bus endeavors to move forward. These six key barriers are listed below in Table-1.

5.1 Key Technological Barriers

LACK OF KNOWLEDGE: In general, cities lack the information needed to make informed decisions at almost all stages, from establishing an initial discussion to scaling up e-buses en masse. Cities lack both general knowledge on the barriers and enablers to implementing their e-bus fleet and city-specific data on the operational viability of their e-buses. Specifically, there is a lack of relevant information and data for cities to determine several key considerations:

- The proper inputs required for an initial cost-benefit analysis of the e-buses and infrastructure
- Strategies and techniques to optimize the design and implementation of an e-bus project
- The operational characteristics, limitations, and maintenance requirements of e-buses available on the market
- Infrastructure planning needs to be completed prior to adoption

TECHNICAL LIMITATIONS OF THE E-BUSES AND CHARGING INFRASTRUCTURE:

Technological limitations exist in all three components of the e-bus trade space:

- Vehicles and batteries produce limited range and power relative to conventional buses. The battery manufacturing industry, nascent and immature, faces a learning curve in its effort to produce reliable, road-tested products.

- Agencies and operators lack the knowledge needed to adopt new operation models to accommodate for the range and power limitations of e-buses.
- Grid and charging infrastructure are also new and evolving technologies that face limitations and stability challenges.

5.2 Key Financial Barriers

DIFFICULTIES FOR AGENCIES IN CHANGING PROCUREMENT PRACTICES: Transit agencies and government institutions typically use rigid financial management models, which incentivize low-cost, low-risk procurement. Most procurement models do not consider the unique cost structure (more expensive up front but cheaper to operate than conventional buses) and uncertain risks inherent in e-buses and their corresponding infrastructure. Traditional procurement practices also do not allocate responsibilities for the new tasks associated with e-bus operations, such as maintaining the batteries and grid infrastructure. Although the total lifetime cost of owning e-buses is often lower than that of conventional buses, and agencies may recognize that a new approach toward procurement is needed, traditional models often prove difficult to change.

LACK OF LONG-TERM, SCALABLE FINANCING OPTIONS: Given the risk, uncertainty, and nascency surrounding the e-bus industry, financing is a tremendous barrier that must be overcome if e-buses are to be implemented on a large scale. This is particularly true for municipalities that have not demonstrated strong credit worthiness with past investments. Scaling e-bus projects requires a large, risk tolerant capital investment, both to procure the vehicles and to supply the necessary charging infrastructure and grid upgrades. Often no financial institutions are willing to make this investment, outside of small-scale pilot projects. Thus, the e-bus fleets in many cities are currently operating as nonscalable demonstrations.

5.3 Key Institutional Barriers

LACK OF LEADERSHIP AND PRAGMATIC PUBLIC POLICY: One of the most frequently cited institutional barriers was the lack of enabling public policies and/or a specific implementation plan to guide e-bus adoption. In many cities, there are either (1) no laws or roadmaps to provide a strategy plan or financial backing for implementing e-buses, or (2) ineffective plans in place that lack clear goals and financial incentives. One main reason that guidelines and policies are not created and/or implemented is the lack of genuine interest from politicians and key stakeholders. When there are limited incentives and lackluster political support, it can be difficult for some cities to issue appropriate tenders to procure e-buses.

Table-1: Barriers Matrix

		GENERAL BARRIERS		
		Technological	**Financial**	**Institutional**
E-BUS TRADESPACE ELEMENTS	Vehicles and batteries	• Lack of information on the advantages and disadvantages of e-buses • Range and power limitations of e-buses • Design flaws in e-buses • Disjointed or limited e-bus marketplace	• High up-front capital costs of e-buses • Lack of financing options	• Difficulties for manufacturers in engaging with cities • Lack of a plan to remove current bus stock
	Agencies and operators	• Lack of information on how to start • Lack of operational data	• Rigid financial management and business models • Scaling investment past initial pilot programs	• No enabling policies supporting adoption of e-buses • Negative public perception • Coordinating maintenance duties • Weak governmental coordination • Informal transit
	Grid and charging infrastructure	• Lack of understanding of the requirements to upgrade infrastructure • Limitations of the charging ports and stations • Grid instability • Lack of standards and regulations on charging infrastructure	• Large capital expenses for grid infrastructure • Difficult to determine grid infrastructure responsibilities	• Lack of space and land to install infrastructure • Limited planning for long-term implications

Source: Barriers to Adopting Electric Buses, World Resources Institute

LACK OF INSTITUTIONAL AUTHORITY, FUNDING, AND LAND: In many cases, a major barrier to initiating or furthering e-bus projects was the lack of institutional capacity. Some cities lack the resources or jurisdictional authority to coordinate an e-bus project. Informal transit posed a noteworthy barrier for many cities, since the owners and operators of informal transit vehicles are typically not accountable to transit agencies or other government bodies.

The lack of government access to land and property also presented a substantial barrier to upgrading and installing the charging and grid infrastructure that e-bus projects require. Charging infrastructure requires land with permanent space to house it, which is often very difficult to find for transit agencies and municipalities. While property ownership issues are not conventionally thought of as barriers to e-bus adoption, owning and/or having permanent contracts over land to install and manage charging infrastructure is often crucial, especially as e-bus fleets are scaled up.

Chapter 6: Enabling Electric Bus Adoption in Cities

The transport sector is undergoing a particularly important transformation. As part of this revolution, cities around the world have begun to consider integrating electric buses into their transit fleets. E-buses have been tested and adopted in several major metropolitan areas in the past decade. However, nearly all the cities adopting e-buses are located in China, Europe, and the United States. Challenges exist to expanding the adoption of e-buses around the world, especially in the global South. In general, the barriers lie in three major categories—technological, financial, and institutional—and deal with issues related to vehicles and batteries, operations, and charging infrastructure. However, a systematic review of potential solutions and an adoption framework are seldom provided for cities that need help adopting electric buses.

This section provides actionable guidance for transit agencies and bus operating entities to help them overcome the most common and debilitating barriers to e-bus adoption. WRI analyzed e-bus activities in 16 cities as case studies to ensure that all recommendations are rooted in real-world experiences. The case studies were selected to reflect a wide range of geographies and levels of experience in e-bus adoption, with a focus on the global South. The research was completed through a literature review of academic papers and reports, interviews, and on-the-ground gathering of information from primary sources.

WRI research focuses on two key questions: What pathways have cities taken toward electric bus adoption? And what are the enabling conditions for electric bus adoption in cities? These questions helped us identify key actions that cities have taken to adopt e-buses under different circumstances.

6.1 Different Stages of E-Bus Adoption

Based on city actions taken to date, we developed a categorization system to assess the relative progress made by each of the 16 cities toward mass e-bus adoption. The cities are predominantly from the global South but two cities from the United States and Europe (Philadelphia and Madrid) are also included because their advancement in e-bus adoption can provide some useful information for other cities. Specific city-level actions were also categorized as either policy- or implementation-based actions:

POLICY-BASED ACTIONS: The city government has considered or is actively considering specific e-bus policies or adoption targets.

IMPLEMENTATION-BASED ACTIONS: The city (or some operators) has procured and is operating e-buses either as a pilot or as part of its public transit operations.

The extent to which each of the 16 cities has taken concrete policy and/or implementation actions was evaluated to place each city into one of five categories, called Stages 0 to 4. Cities can use this evaluation system as a guide to determine where they stand in terms of their stage of electric bus adoption.

6.2 Solutions to Enable E-Bus Adoption in Cities

Transit agencies and bus operating entities are encouraged to maximize electric bus adoption targets based on local conditions, and to develop a responsible strategy for implementation. Here is step-by-step guidance to establish and achieve e-bus adoption targets using concrete and diverse real-world experiences. Nine steps are recommended to be taken by stakeholders interested in moving toward full e-bus adoption (Figure 6). The first five steps cover initial preparation and planning, and the next four steps address how to scale up to reach mass e-bus adoption.

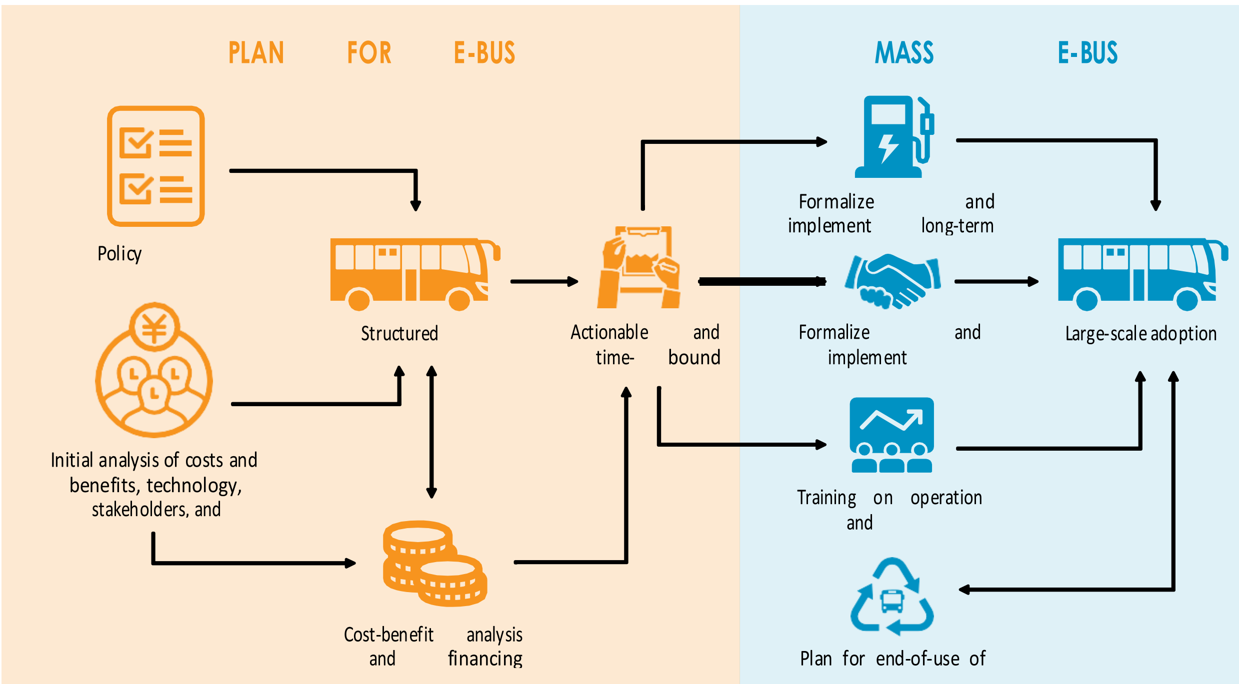


Figure 6 | Enabling Factors and Actions in the Planning and Scaled-Up Lifecycle of E-Bus Adoption

6.3 Initial preparation and planning for e-bus adoption

The most difficult step toward any bold transformation is making the decision to get started. Information provided in this section is intended to make that decision as easy as possible. Five major steps are described in this section for building an actionable e-bus adoption plan:

1. **Consider the policy landscape.** Before starting any project, transit agencies and bus operators should review existing policies in the country and city, either supportive of, obstructive to, or indirect to electric bus adoption; analyze the potential impact of their adoption of e-buses; and analyze the potential impact if the policies were to change. City officials who want to increase the e-bus fleet size of the city should also consider the potential to use different policy instruments to incentivize adoption, and coordinate between sectors to facilitate effective policy implementation.

2. **Perform an initial analysis.** When the project is starting from scratch, questions that arise should be answered based on concrete analysis. It is key for transit agencies and bus operating entities to conduct an initial analysis to understand the following: the total cost of owning electric buses; the environmental and social benefits generally and in the local context; the existing and potential new stakeholders; the constraints of adopting electric buses in the city; and any potential solutions to address the constraints. If cities lack sufficient capacity to conduct any part of this analysis, they can reach out to peers or research institutes for help.
3. **Launch a structured pilot project.** Cities should avoid "analysis paralysis" by taking action and gaining practical experience. Pilot projects are a low-barrier opportunity for cities to test ideas and learn by doing. A good electric bus pilot project has clear definitions on the scale and timing, specifies the data needed, includes data collection mechanisms, and plans ahead for charging infrastructure regardless of the scale of the current e-bus fleet. In addition, choosing more than one bus model to test can reduce the vulnerability of the project and give more flexibility for the city to adapt to technology upgrades. Lastly, it is important to have a flexible planning process that takes into account emerging results and lessons learned through trial and error and that supports information sharing and peer learning.
4. **Update the cost-benefit analysis and explore financing options.** Based on the initial analysis and operational data collected, a more advanced cost-benefit analysis of the project should be conducted. Different financing options should also be researched and analyzed to ensure the electric bus adoption plan will be sustainable over the long term. Considering that transit agencies and bus operating entities normally do not monetize the environmental benefits of reduced pollution from the public transport sector, the results of the cost-benefit analysis and financial analysis may differ, leaving room for innovative financing mechanisms.
5. **Set actionable and time-bound targets.** Targets are easy to set but hard to follow if they are not analysis-based, actionable, and time- bound. Stakeholders should work together to reduce duplicative efforts or miscommunication and define a reliable electric bus adoption target for the city based on the city's ambition and information collected. This can also improve the actionability of the project and help ensure the targets are achieved.

6.4 Reaching mass e-bus adoption

Scaling e-bus implementation is a fundamental challenge to fully adopting e-bus fleets but is often given too little attention at the outset of an e-bus program. While many cities around the world have successfully initiated e-bus pilot programs, very few2 to date have been able to move e-buses to the mainstream and position them as a substantial percentage of their entire bus fleets. Four major steps are described in this report for expanding the scale and quality of an e-bus fleet:

1. **Formalize and implement a long-term infrastructure plan.** Charging infrastructure is one of the most important features of electric buses that conventional buses do not share. Having sufficient infrastructure is paramount to the success of large-scale electric bus adoption due to the increased complexity of an e-bus network. A few aspects should be planned ahead by the transit agency and bus operating entity together with the utility and urban planning sectors: creating a site plan to address the reality of land scarcity; analyzing and defining the technical specifications of charging stations; exploring innovative charging mechanisms, such as smart charging; and developing plans to deal with power outages. In addition, infrastructure-related expenses, which are often underestimated, should be carefully evaluated.
2. **Formalize and implement an e-bus procurement plan.** As e-buses use a relatively new technology with limited operational experience, transit agencies and bus operating entities should integrate the technological uncertainties into formalized procurement plans. Specific technical details should be defined in the procurement plan, which could be customized to assure the public transport service of the city. Since the technology is evolving quickly, future technology advancement should be considered. The procurement models that work for the city should be carefully studied and analyzed and, ideally, should help incentivize electric bus adoption and reduce the costs and risks for bus operating entities.
3. **Train bus operators—a necessary but often overlooked step in electric bus adoption.** Training can help improve the operation behavior of drivers, increase the efficiency of buses, extend the life of batteries, and reduce the need for maintenance. These can help decrease the operation and maintenance expenses for the operators
4. **Plan for end-of-use for each e-bus.** E-bus batteries can be harmful to the environment if they are not handled responsibly at the end of their lifespans. Meanwhile, the residual value of e-bus batteries is poorly defined due to the evolving nature of the technology. This potential environmental harm and economic uncertainty for electric buses requires the transit agency and bus operating entity to carefully craft a responsible retirement plan for each electric bus and explore innovative bus and battery scrappage mechanisms with other stakeholders, especially bus and battery manufacturers, to reduce the total costs and risks. This, in turn, can help incentivize the adoption of electric buses and reduce the negative impacts on the environment.

6.5 Recommended Key Actions for Cities at Different Development Stages

Based on the enabling conditions identified in our analysis of the 16 case study cities, we recommend that in addition to following our general guidelines for e-bus adoption cities emphasize the key actions described in Figure 7.

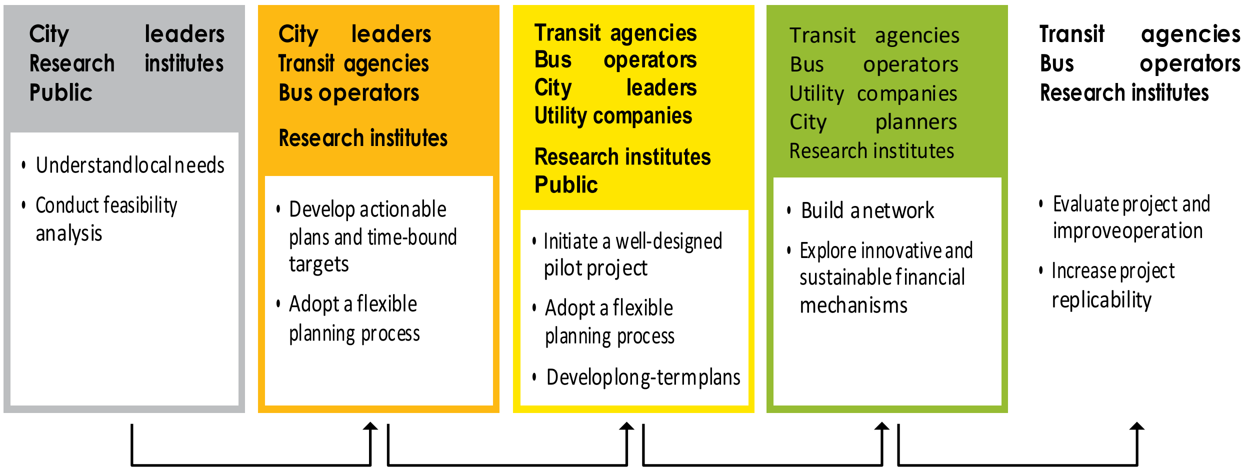


Figure 7 | Key Actions for City Stakeholders at Different Development Stages

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