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Energy Consumption, Emission, Transportation Sector in Malaysia: Review on Malaysia's Road Transport

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Abstract: Transportation is a major challenge for energy conservation, with road transport in Malaysia being a significant contributor to greenhouse gas (GHG) emissions. In Malaysia, traditional fossil fuels such as gasoline and diesel dominate the transportation sector, which has become the second-largest source of GHG emissions, accounting for 20% in 2014. This increase in CO2 emissions, driven by rising vehicle ownership and economic growth, underscores the urgent need for effective emission reduction strategies. The rapid growth in road transportation in Malaysia is linked to socioeconomic factors, including rising incomes and urbanization, leading to higher energy consumption and pollution. Data indicates a significant increase in vehicle registrations from 1990 to 2018, with motorcars and motorcycles being the most common. This growth, fueled by subsidies and decentralization, has exacerbated the sector's environmental impact. The Green Technology Master Plan Malaysia 2017–2040 aims to address these issues by setting ambitious targets to enhance renewable energy, improve energy efficiency, and promote eco-friendly fuels. Key strategies include expanding public transportation, increasing the adoption of electric vehicles (EVs), and introducing alternative fuels like hydrogen. Malaysia has substantial potential to reduce CO2 emissions through initiatives such as expanding EV infrastructure, promoting natural gas vehicles, and improving public transit. Effective implementation of these strategies can significantly lower the transportation sector's carbon footprint, contributing to a more sustainable future.

Keywords: *Energy Consumption, Emission, Transportation, Road Transport, Carbon Dioxide (CO_2)*

1. Introduction

One of the most difficult areas for energy conservation is road transportation. Transportation-related consumption accounts for an increasing percentage of total gasoline consumption. In Malaysia, traditional fossil fuels such as gasoline, diesel, and electricity are still used for transportation and these activities produce millions of tonnes of greenhouse gases (GHG) every year. According to the United Nations Framework Convention on Climate Change (UNFCC), the transportation sector has consistently remained the country's second-largest source of greenhouse gas emissions, accounting for 20% of total GHG emissions in 2014. Malaysia is an oil-based economy, with almost all economic sectors, from industry to transportation to domestic operation, relying on fossil fuels in general and oil energy in particular (Azam et al., 2015)

Furthermore, CO2 emissions have risen rapidly in recent decades, and these massive CO2 emissions from the burning of fossil fuels, as well as their climatic effects, have become important issues that must be addressed. Electricity generation, transportation, industrial, and residential are the main sectors identified to contribute to the emission of CO2 in Malaysia.

Table 1 shows the global final energy consumption from 1973 to 2016. The growth of global final energy consumption has increased by 3752.8 Mtoe from 1973 to 2008. Then, for just 8 years, there is a spike increase of around 48789.5 Mtoe (2008-2016). The major contributors to growth were the transportation sectors which increased almost 14.7% from 2008 to 2016. Road transportation is the largest contributor to emissions in the transport sector which about 18% comes from it. From the trend of total road transport as shown in Figure 1, demand for road transport is unlikely to decrease in the future as it shows a positive increase from the year

1990 to 2018 and still moving upward.

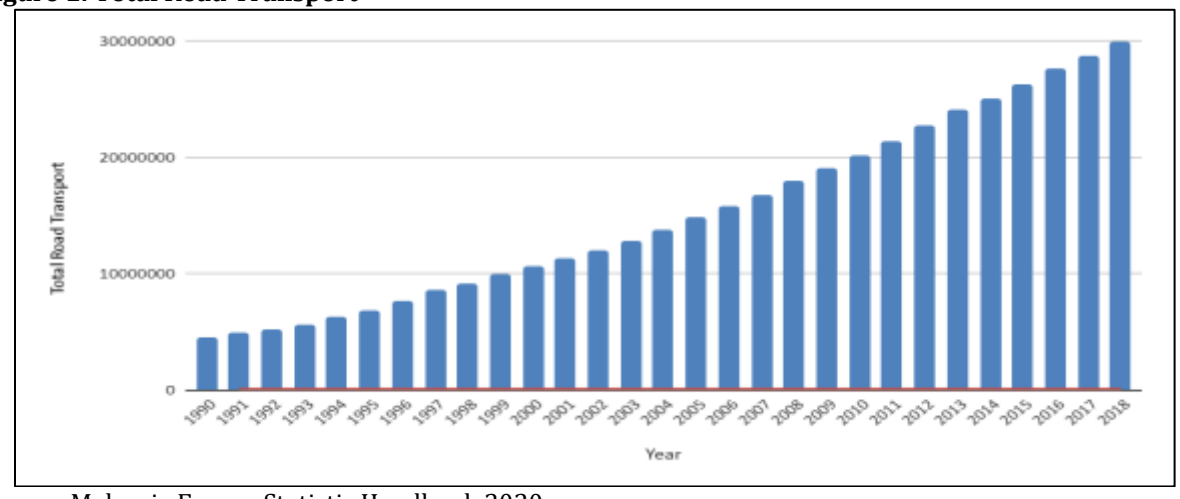
Table 1: Global final energy consumption by sector

Sector	1973		2008		2016	
	Mtoe	Share (%)	Mtoe	Share (%)	Mtoe	Share (%)
Industry	1544.6	33.0	2345.1	27.8	16019	28
Transport	1081.2	23.1	2299.4	27.3	24004	42
Agriculture/Commerce/Civil	1764.6	37.7	3036.9	36.0	8464	14.7
Non-energy use	285.3	6.1	747.1	8.9	8729	15.3
TOTAL	**4675.7**	**100**	**8428.5**	**100**	**57218**	**100**

Source: Malaysia Energy Statistic Handbook 2020

Malaysia's private vehicle population has risen year after year, owing to increasing income levels and unregulated city growth. This leads to an increase in energy consumption, especially from fossil fuels, and, as a result, an increase in air pollution as a result of their combustion. Since transportation systems rely on petroleum oil, which is a limited resource in Malaysia, it is essential to prepare for energy efficiency in this sector to reduce the rapid use of petroleum oils and increase air pollution, especially CO2. According to Dai et al., (2023), improvements in transport infrastructure are associated with increased economic growth. However, this growth often leads to higher CO2 emissions from the transport sector due to increased vehicle usage and fossil fuel consumption. This worrying number certainly caused the government of Malaysia to commit to a deep cut in CO2 emissions by reducing 45% in the year 2030 (Ooi & Amran, 2019). Segar et al., (2024) also predict specific emission levels for the coming years, underscoring the urgent need for effective mitigation strategies. To make it come true, reduction of CO2 emissions from road transport is important. This can be done by improving the governance of regulators' principles and guidelines (Peiseler & Serrenho, 2022). This is because having better administration, more effective compliance and targeted enforcement of regulation can help to achieve the desired outcomes most efficiently. As a result of the aforementioned concerns about CO2 emissions in road transportation, a study is needed to investigate effective policy options in the context of Malaysia. This paper focuses on analyzing energy use and emissions in road transportation in Malaysia, to investigate the optimal level of CO2 emissions that can be reduced from this sector.

Figure 1: Total Road Transport



Source: Malaysia Energy Statistic Handbook 2020

2. Road Transportation Pattern in Malaysia

Transportation networks are inextricably linked to socioeconomic shifts because of the versatility it offers. In addition, transportation infrastructures can ensure access to markets and services, thus economic opportunities are likely to emerge. Transportation networks on a global, regional, and local scale have all become critical components of economic activity. As a result, trade and distribution are becoming increasingly

important. However, while transportation has a positive effect on socioeconomic structures, it also has drawbacks such as traffic congestion, accidents, mobility gaps, and environmental impact.

The ever-increasing demand for transportation and the expansion of the road network in Malaysia signify the rapid growth of road-based motorization. According to the Department of Statistics (2012), Malaysian road transport is predominantly composed of motorcars, motorcycles, taxis, buses, and goods vehicles. Table 2 shows the percentage of registered road transport vehicles in Malaysia for various years. With 47% and 46%, respectively, motorcars and motorcycles are the most popular modes of transportation correspondingly. The table also shows spectacular rises in motor vehicle registration rates and it is obvious that Malaysia's rapidly expanding car market is a direct result of stellar economic success and the significant economic contribution they make to the country's overall growth.

Table 2: Registered Road Transport Vehicles in Malaysia

Year	Motorcars	Motorcycles	Taxi	Busses	Good vehicles	Others	Total
1990	33.15	55.58	0.63	0.49	6.96	3.19	100
1995	37.02	52.32	0.80	0.52	6.39	2.95	100
2000	39.12	50.54	0.63	0.46	6.28	2.98	100
2005	43.69	47.30	0.53	0.39	5.43	2.66	100
2009	44.73	47.01	0.42	0.35	4.92	2.57	100
2014	53.42	40.50	0.54	0.10	3.12	1.90	100
2018	47.12	46.46	1.04	0.08	3.33	2.42	100

Source: Malaysia Energy Statistic Handbook 2020

Based on the growth of road transport shown in Table 3 below, from about 4.5 million in 1990 to 29.5 million in 2018, the number of motor vehicles in Malaysia increased by 7.1 percent per year on average. From this growth, passenger cars and motorcycles contribute to about 94% of the vehicles in the country. There are several reasons leading to the rapid growth in total road transportation in Malaysia.

Table 3: Growth of total transport in Malaysia from year 1990 to 2018

Year	Total Road Transport	Growth
1990	4,547,414	9.44
1995	6,897,434	10.3
2000	10,598,804	6.74
2005	14,816,407	7.64
2010	20,188,565	6.17
2015	26,301,952	4.78
2016	27,611,846	4.98
2017	28,737,696	4.08
2018	29,956,292	4.24

Source: Malaysia Energy Statistic Handbook 2020

Increased population size and disposable incomes, as well as fuel subsidies and decentralization, all lead to a rise in the number of vehicles in Malaysia. Malaysia's national car schemes have also contributed to the growth of motor vehicles by narrowing the government's options. The rapid rise in vehicle numbers was also helped by the growing population and urbanization. According to Dargay and Gately (1999), there is a positive relationship between wages, GDP, and transportation demand. This is factual in Malaysia, where rising GDP and income have made private motor vehicles more affordable and led to the growing demand for transportation services (Kasipillai and Chan, 2008). The debate over fuel subsidies, including their eventual reduction or removal, has direct implications for Malaysia's transportation sector, which consumes 40% of the country's total resources and is entirely reliant on fossil fuels (Oh et al., 2018). Subsidies obscure the true cost of transportation, meaning that motor vehicle users do not currently pay the full cost of travel, including

externalities like emissions, congestion, and injuries (Meyer et al., 1965). Consequently, Malaysia has experienced rapid motorization due to these artificially low prices. In terms of motor vehicle use, decentralization is a double-edged sword. Decentralization resulted in the same travel times, longer distances, and less congestion. As a result of public transportation's failure to reach many of the outlying areas, car dependence grew. Moreover, Malaysia's public transportation system is also in its infancy, thus due to the lack of established public transportation and high mobility, the number of private transportation grew rapidly in tandem with rising economic capability (Mustapa & Bekhet, 2016).

3. Emissions

According to Danielis (1995), it has been found that atmospheric concentrations of greenhouse gases such as carbon dioxide (CO2), sulfur dioxide (SO2), carbon monoxide (CO), sulfur dioxide (SO2), and nitrogen oxide (NOx) have increased in recent decades. All these gases significantly have a negative environmental impact. This effect is linked to the rising transportation trend. As mentioned earlier, the transportation sector is the world's second-largest source of carbon emissions, with road transportation accounting for a significant portion of this. According to Zhu et al (2019), the road transportation industry in six Asia-Pacific countries such as Australia, Canada, China, India, Russia, and the United States already accounts for more than half of the global transportation industry's carbon emissions.

In Malaysia, the transportation sector accounts for 28% of total CO2 emissions, of which 85% comes from road transport (Mustapa, & Bekhet 2016). Since conventional vehicles also use fossil fuels as their primary energy source, transportation is one of the major contributors to greenhouse gas (GHG) emissions. Furthermore, transportation-related CO2 emissions are the fastest-growing source of CO2, with the vast majority of estimated rises coming from developing countries. According to Ong et al. (2012), the transportation sector is contributing an increasing share of total emissions. Chandran and Tang (2013) state that energy consumption in the road transportation sector contributes significantly to environmental pollution in Malaysia, especially CO2 emissions. Solaymani (2022) identifies trends and patterns in transport-related CO2 emissions over recent years, showing an increasing trajectory largely driven by economic growth, urbanization, and rising vehicle ownership.

Figure 2 below shows the final energy consumption for every sector in Malaysia. Since 1997, the transportation sector has shown high energy consumption, and this reinforces the fact that transportation is the largest contributor to CO2 emissions.

Figure 2: Final Energy Consumption in Malaysia, Sources: Ahmad et. al., (2021)

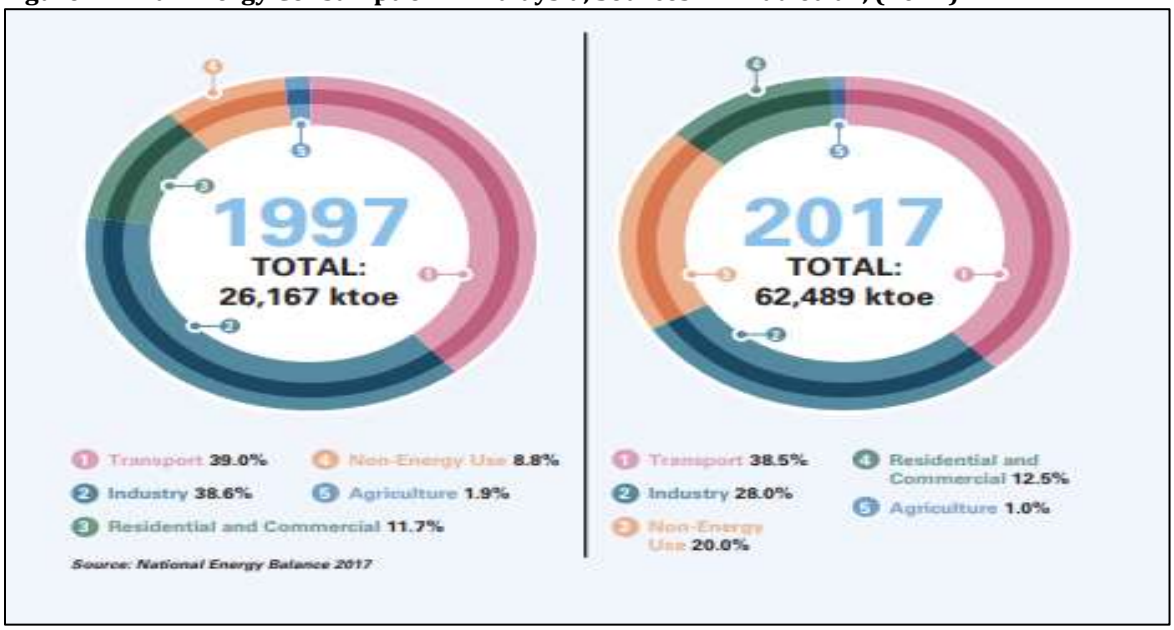


Table 4 shows the trend of energy use by the transportation sector based on fuel types in Malaysia. The transportation sector's overall energy usage rose from 7.83 Mtoe in 1995 to 24 Mtoe in 2016. With an average growth rate of 5.7 percent, this strong growth rate is more than double that of the previous year. In Malaysia, coal, diesel, aviation turbine fuel (AVF), aviation gasoline (AV gas), fuel oil, natural gas, and electricity were all used in the transportation sector. The primary source of energy is fossil fuel, with petrol being the most common, followed by diesel, ATF, and AV gas. Thus, it depicts petroleum products, with diesel and petrol accounting for more than 70% of crude oil products, the two most popular transportation fuels in Malaysia. Based on this fact, petrol consumption in the transportation sector was the primary driver of growth in 2016, with a positive trend of 6% in 2016.

Table 4: Energy use by the transportation sector in Malaysia

Year	Petrol	Diesel	ATF and AV gas	Fuel Oil	Natural gas	Biodiesel	Electricity	Total
1995	4477	2168	1160	17	5	0	0	7827
1996	5161	2417	1335	32	4	0	1	8950
1997	5574	3106	1439	75	5	0	1	10200
1998	5849	2311	1619	9	4	0	1	9793
1999	6778	3174	1424	13	0	0	4	11393
2000	6378	4103	1574	4	7	0	4	12070
2001	6820	4534	1762	5	14	0	5	13140
2002	6940	4680	1785	4	28	0	4	13441
2003	7352	5019	1852	3	40	0	5	14271
2004	7867	5398	2056	4	54	0	6	15385
2005	8138	5132	2010	4	95	0	5	15384
2006	7838	4726	2152	3	120	0	5	14844
2007	8549	4859	2155	3	147	0	4	15717
2008	8788	5283	2112	3	194	0	15	16395
2009	8667	5063	2120	21	236	0	12	16119
2010	9476	4694	2380	12	247	0	18	16827
2011	7995	6169	2553	39	272	24	18	17070
2012	8617	5610	2522	5	292	115	21	17182
2013	12288	6510	2998	60	289	188	21	22354
2014	12333	8259	3158	0	276	279	22	24327
2015	12554	7068	3134	4	264	389	23	23436
2016	13302	7044	3019	14	208	389	29	24005

Source: Malaysia Energy Statistic Handbook 2020

Table 5: Road Transport by Type and Engine Type

Year	Vehicle Type	Petrol	Share (%)	Diesel	Share (%)
2014	Motorcycles	540,341	47.15	45	0.16
	Passenger Cars	591,796	51.64	2,207	7.65
	Busses	-	0.00	122	0.42
	Taxis	1,022	0.09	3	0.01
	Taxi/ Hire Cars	2,199	0.19	14	0.05
	Goods Vehicles	3,810	0.33	9,393	32.56
	Others	6,774	0.59	17,067	59.16
	TOTAL	**1,145,942**	**100**	**28851**	**100**

2015	Motorcycles	464,883	43.24	6	0.03
	Passenger Cars	594,688	55.31	1,712	7.53
	Busses	-	0.00	63	0.28
	Taxis	565	0.05	4	0.02
	Taxi/ Hire Cars	3,486	0.32	6	0.03
	Goods Vehicles	4,015	0.37	7,358	32.36
	Others	7,536	0.70	13,589	59.76
	TOTAL	**1,075,173**	**100**	**22738**	**100**
2016	Motorcycles	464,612	46.52	5	0.03
	Passenger Cars	516,338	51.70	1,242	6.45
	Busses	-	0.00	34	0.18
	Taxis	844	0.08	-	0.00
	Taxi/ Hire Cars	4,306	0.43	3	0.02
	Goods Vehicles	3,675	0.37	6,085	31.58
	Others	9,011	0.90	11,898	61.75
	TOTAL	**998,786**	**100**	**19267**	**100**
2017	Motorcycles	495,198	48.47	4	0.02
	Passenger Cars	506,531	49.58	1,757	8.36
	Busses	-	0.00	17	0.08
	Taxis	484	0.05	-	0.00
	Taxi/ Hire Cars	3,064	0.30	4	0.02
	Goods Vehicles	3,059	0.30	6,339	30.17
	Others	13,268	1.30	12,889	61.35
	TOTAL	**1,021,604**	**100**	**21010**	**100**
2018	Motorcycles	552,035	50.01	4	0.02
	Passenger Cars	528,468	47.87	3,316	13.77
	Busses	-	0.00	5	0.02
	Taxis	542	0.05	-	0.00
	Taxi/ Hire Cars	5,961	0.54	8	0.03
	Goods Vehicles	3,061	0.28	6,967	28.93
	Others	13,872	1.26	13,783	57.23
	TOTAL	**1,103,939**	**100**	**24083**	**100**

Source: Malaysia Energy Statistic Handbook 2020

70% of petrol consumption comes from passenger cars as well as motorcycles. Based on Table 5, reveals that passenger cars lead to a high percentage of usage of petrol which is more than 50% of the total number of vehicles. Meanwhile, in 2018, motorcycles led the consumption of petrol. This is because of the high rise of motorcycles in Malaysia during that year. These two types of vehicles mostly use petroleum products for fuel. For diesel, other vehicle types as well as good vehicles contribute the largest consumption every year. This means that private transportation is the main source of CO2 pollution from road travel. As previously mentioned, the country has seen exponential growth in the number of private cars over the last two decades. It is predicted that it will continue to grow in the coming years. As a result, controlling emissions from private vehicles is the most difficult challenge in Malaysia's transportation sector in terms of reducing GHG emissions.

4. Green Technology Master Plan Malaysia 2017–2030

Ministry of Energy, Green Technology and Water Malaysia (KeTTHA) (2017)published the 'Green Technology Master Plan Malaysia 2017–2040' in June 2017, outlining strategic strategies to build green technology and establish a low-carbon, resource-efficient economy and lay out the country's immediate path for green development. Malaysia's priorities in the power and transportation sectors are outlined in the master plan. The three goals of the power sector are first, to expand renewable energy generation capacity to 25% in 2025 and 30% in 2030, secondly to introduce highly efficient coal-fired power, and to promote cogeneration for more efficient power generation. Lastly to reduce consumption of the residential and commercial sectors by 10% in 2025 and 15% by 2030.

As transportation contributes the highest emission, then this plan also touches on the transport sector's three-pronged approach to reducing CO2 emission. First, to double the modal share of public transport from 20.8% in 2018 to 40% in 2030. Second, to change the ratio of EEVs to private vehicles from 32.6% in 2015 to 100% in 2030. Third, to promote the introduction of eco-friendly fuels such as palm oil.

5. Malaysian Potential in CO2 Reduction

Malaysia's transportation sector is one of the major contributors to the country's greenhouse gas (GHG) emissions. In 2017, the transportation sector accounted for 22% of Malaysia's total GHG emissions, with road transport being the largest contributor. However, Malaysia has the potential to reduce its CO2 emissions from transportation through various initiatives.

One of the key initiatives is the promotion of electric vehicles (EVs) and the development of EV infrastructure. In 2019, the Malaysian government announced a target of having 100,000 EVs on the road by 2030, with plans to increase the number of EV charging stations across the country. In addition, the government has also provided incentives for the purchase of EVs, including exemptions from import duties and sales tax (MIDA, 2019). Transitioning road vehicles from traditional fossil fuels to natural gas can significantly lower CO2 emissions. Natural gas burns cleaner than gasoline or diesel, producing fewer greenhouse gases and pollutants. Encouraging the adoption of NGVs through incentives and supportive policies can contribute to a more sustainable transportation system. Solaymani (2022) suggests providing financial incentives and subsidies for the purchase and use of electric, hybrid, and other low-emission vehicles.

Another initiative is the promotion of public transportation, including the expansion of rail networks and the introduction of bus rapid transit systems. The government has also introduced policies to encourage the use of public transportation, including the implementation of congestion charges and the introduction of a cashless payment system for public transportation. Enhancing public transportation in terms of capacity, coverage, and quality is crucial for reducing reliance on private vehicles. Investments in expanding and improving public transit infrastructure, such as buses, trains, and light rail systems, can make public transport a more attractive option. This, in turn, reduces the number of vehicles on the road, thereby lowering CO2 emissions and easing traffic congestion.

Furthermore, Malaysia has also been exploring the use of alternative fuels, including biofuels and hydrogen fuel cells, for transportation. In 2019, Malaysia's first hydrogen fuel cell electric vehicle was unveiled, with plans to expand the use of hydrogen fuel cell technology in the transportation sector. According to a recent study by Al-Amin & Doberstein (2019), the adoption of hydrogen fuel cell vehicles in Malaysia could result in a significant reduction in CO2 emissions. The study found that the use of hydrogen fuel cell vehicles could result in a reduction of up to 60% in CO2 emissions from the transportation sector in Malaysia by 2050. Biodiesel is a renewable alternative to conventional diesel fuel, capable of reducing CO2 and CO emissions by 62% to 36%. Encouraging the production and use of biodiesel, especially in heavy-duty vehicles and public transport, can substantially decrease the overall carbon footprint of the transportation sector.

In addition, the government can implement taxation and pricing policies aimed at reducing CO2 emissions by making high-emission vehicles and fuels more expensive and promoting low-emission alternatives. This includes higher taxes on the purchase and registration of high-emission vehicles, increased fuel taxes, and congestion charges in urban areas. Low-emission vehicles benefit from tax rebates, exemptions, and subsidies, making them more affordable. These policies encourage consumers to choose cleaner transportation options, generate revenue for environmental initiatives, and directly contribute to reducing CO2 emissions and improving air quality. Proper implementation requires public support, infrastructure development, and consideration of economic impacts.

In conclusion, Malaysia has the potential to make significant contributions to CO2 reduction in transportation through the promotion of EVs and the development of EV infrastructure, the promotion of public transportation, and the exploration of alternative fuels. The adoption of hydrogen fuel cell vehicles, in particular, could result in a significant reduction in CO2 emissions.

Conclusion

In conclusion, addressing CO2 emissions from road transportation in Malaysia is a multifaceted challenge that requires a comprehensive approach. The significant rise in private vehicle use, primarily fueled by economic growth and government policies, has led to increased energy consumption and emissions. The Green Technology Master Plan Malaysia 2017–2040 sets ambitious targets for reducing CO2 emissions by enhancing renewable energy generation, improving energy efficiency, and promoting eco-friendly fuels. Key initiatives include the promotion of electric and hydrogen fuel cell vehicles, expansion of EV infrastructure, and enhancement of public transportation systems. By implementing these measures, Malaysia can significantly reduce its transportation sector's carbon footprint, contributing to a more sustainable and environmentally friendly future.

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