Chapter 3

Low-carbon Vehicles and Traffic System: Temburong Ecotown Phase 4 Study

February 2021

This chapter should be cited as

ERIA (2021), 'Low-carbon Vehicles and Traffic System: Temburong Ecotown Phase 4 Study', in Kimura, S., et al. (eds.), *Temburong Ecotown Development Phase 4.* ERIA Research Project Report FY2020 no.19, Jakarta: ERIA, pp.82-118.

Chapter 3

Low-Carbon Vehicles and Traffic System: Temburong Ecotown Phase 4 Study

1. Introduction

The transport sector in ASEAN countries accounts for 40%–60% of the total energy demand. The sector is dominated by oil (gasoline and diesel), imports of which have been increasing rapidly in parallel to the slowing down of domestic production, which affects the security of supply (Kutani, 2013). Increased combustion of oil products has worsened the air quality, which potentially has significant socio-economic impacts.

In many cases, there has been an inadequate development in infrastructure for public transport, walking, and cycling due to overbuilt roadways that accelerate more use of private vehicles. The public transport system is inadequate and unreliable there is often the urge to own a private vehicle or a motorised two-wheel vehicle. This also, in turn, makes walking and cycling redundant, mainly due to unfavourable and not-public-friendly walking and cycling pathways. The US Energy Information Administration (2017) pointed out that in 2017, non-OECD Asian countries, including China and India, accounted for more than 70% of the increase in transport fuel consumption in non-OECD countries due to an increase in personal mobility.

Two principal ways can improve the delivery of efficient and sustainable transport infrastructure, which is essential for a town, city, or urban area aspiring to be energy-efficient and environment-friendly. These ways are the use of information and communications technology (ICT) and the electrification of mobility.

The use of ICT to support better transport infrastructure is called intelligent transport system (ITS). UNESCAP (2014) defined ITS as combinations of technologies for increasing efficiency in vehicular traffic. Their most frequent applications are in the road transport sector, such as electronic sensors, geo-positioning navigation systems, video surveillance devices, vehicle probes, and wireless communications. These applications enable data to be accumulated, analysed, and communicated in real-time, or near real-time, in ways that can greatly improve traffic efficiency and safety.

This study for developing a low-carbon transport system in Temburong shall focus on the use of more efficient vehicle technology, propulsion, and energy. Therefore, it shall analyse the electrification of mobility, the second principal way. Nowadays, we are witnessing electro-mobility as a fast-growing technological and social trend, which has become one of the main opportunities and challenges for smart cities. The opportunity lies in the fact that penetration of electric vehicles (EVs) would help shift oil consumption to electricity, reducing on-street greenhouse gas (GHG) emissions and air pollution and reaching a higher energy efficiency in mobility. On the other hand, however, smart cities need to build smart infrastructure for the EVs' electric charging (Xu et al., 2016; Wagner et al., 2014).

Often considered within the category of EVs are hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), full battery electric vehicles (BEVs), and fuel-cell hydrogen-electric vehicles (FCEVs). Electricity produced in these four EV types is different. In the HEVs, electricity is produced by the braking mechanism; in PHEVs and BEVs, electricity is produced in the grid system and fed into the vehicle's battery unit during charging. In FCEVs, electricity is produced by electrochemical oxidation of hydrogen in the vehicle's fuel cell unit that is equipped with hydrogen storage.

This report proposes two levels of analysis. In section 3.2, we analysed the possibility of having low-carbon vehicles, i.e. battery electric cars or hydrogen-powered fuel cell cars in Brunei Darussalam in the horizon of 2050. In that section, we analysed the impacts of each new car technology on energy use and carbon dioxide (CO_2) emissions at the national level. In section 3.3, we proposed a low-carbon traffic system for Temburong district concerning the possible technological options for passenger cars proposed at the national level (section 3.2).

Through this approach, this report should provide a technological framework that contains options for policymakers to develop a low-carbon road transport sector, especially in terms of passenger cars. It should also provide a policy framework containing mobility-related policy options that should support developing Temburong into an ecotown.

2. Perspective of Low-Carbon Vehicles for Brunei Darussalam

2.1. Trends, policies, and possibilities

Electromobility is developing rapidly. The global electric car fleet is estimated to exceed 5.1 million, which is 2.0 million more than in the previous year and almost double the earlier sales of new electric cars (IEA, 2019). The number of EVs nearly tripled globally since 2005 (Raposo and Cuiffo, 2019).

China is the world's largest market for electric cars, with nearly 1.1 million sold in 2018. With 2.3 million units, it accounts for almost half of the global electric car stock, followed by Europe (1.2 million) and the United States (US) (1.1 million) (IEA, 2019). China started in 2009 with the '10 cities, 10,000 vehicles' business model to promote plug-in electric vehicle (PEV) development. However, it established targets only in June 2012: 500,000 vehicles by 2015 and 5 million by 2020. China aims to reach new EV sales shares of 7%–10% by 2020, 15%–20% by 2025, and 40%–50% by 2030 (Marklines, 2019).

In Japan, a leading EV market, government support for BEV development started in the early '70s. Strong government commitment to promoting EVs is reflected in a heavy emphasis on research and development of vehicle and component technologies, infrastructure, and market support for EV users. The Ministry of Economy, Trade and Industry (METI) funded the Clean Energy Vehicle Introduction Project, which provided subsidies and tax discounts for purchasing EVs (Loveday, 2013).

In 2017, Japan's EV production ranked fourth in the world at around 8%, after China (50%), Europe (21%), and the US (17%) (Lutsey et al., 2018). The government works with industry stakeholders to reduce by 80% GHG emissions from domestically produced vehicles (by 90% for passenger vehicles), including exported vehicles, by 2050, with a combination of HEVs, BEVs, PHEVs, and FCEVs. Under the new policy scenario, Japan targets increasing EV sale share of all modes (excluding two- and three-wheelers) by 21% and scaling up to 37% market share under the EV30@30 scenario in 2030. To provide more charging stations throughout Japan, in 2018, the government set the goal of having fast chargers every 9.3 miles (15 km) or within every 19-mile (30 km) radius (Kane, 2018a). Japan's success in the EV market is due to government commitment, strong support from the automotive industry, and user-friendly infrastructure.

The Government of India, in 2013, established the National Electric Mobility Mission Plan 2020 and, in 2015, enacted Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India or FAME India. The government announced its intention to move towards all-EV sales in 2025–2040 and, through EV30@30 programme, to ensure that EVs will account for at least 30% of all vehicle sales by 2030 (Lutsey et al., 2018; IEA, 2019). All vehicles, including two-wheelers, are targeted for electrification. EVs have penetrated the vans and urban bus markets, accounting for 14% of all passenger cars and light commercial vehicles (LCVs) and 11% of all bus sales (IEA, 2019). As a member of the Electric Vehicle Initiative, India is dedicated to accelerating the deployment of EVs.

Only two ASEAN countries produce and commercialise PEVs – Thailand and Malaysia. Thailand's first PEV development road map – the Electric Vehicle Promotion Plan – was approved by the government in March 2015. In 2017, the Board of Investment approved incentives for manufacturers of BEVs, HEVs, and PHEVs, mostly in the form of corporate tax exemptions for 5 to 8 years. The project to develop next-generation automotive vehicles, focusing on PEVs, was included in the Eastern Economic Corridor, approved in February 2018, to spur investment. In March 2019, the Board of Investment agreed to renew the investment package for HEVs to attract more investment in PEV production. Investors must apply to produce HEVs in 2019 and assemble BEVs within 3 years. HEV and PHEV sales rose by 24.7% in 2017 to 11,945 units whilst BEV sales reached 165 units (Nicholls et al., 2018). Vehicles sold in that year totalled 870,748 units. By 2036, Thailand targets having 1.2 million electric cars on its streets and setting up 690 charging stations.

On 8 August 2019, the Government of Indonesia issued Presidential Decree No. 55/2019 which laid the general framework to accelerate the penetration of (plug-in) battery-based electric vehicles in the country. Before that decree, the Ministry of Industry told a newspaper that the government would target sales of 400,000 EVs by 2025 to reduce GHG emissions by 29% in 2030 (Akhyar, 2019). One source mentioned that 400,000 PEVs would be produced domestically by then. Other sources estimate that around 2 million electric-powered two-wheelers would be sold by 2025. Jakarta has around 1,000 charging stations, built by the PLN (State Electricity Company) (Aji, 2017). On 23 October 2019, the government issued Regulation (PP) no. 73/2019 concerning luxury sale tax of private cars that gives advantage to low CO_2-emitting cars, including the different classes and types of EVs.

FCEVs, on the other hand, are much less developed. The use of hydrogen for FCEV could contribute to decarbonising the road transport sector. FCEVs have zero direct CO_2 emissions when used; they only release water from the tailpipe. Energy use and CO_2 emissions take place then in the phases of hydrogen production and vehicle infrastructure.

2.2. Methodology and scenarios

In this study, we modelled Brunei's national energy systems on the Long-Range Energy Alternatives Planning System (LEAP) software during the Working Group of ERIA's Energy Outlook and Energy Saving Potential Project organised in Jakarta, 3–7 February 2020. Historical data of Brunei's energy consumption from the different sectors and the energy supply system were used to develop the model that contains the relationship between energy demand and supply and the different socio-economic and demographic assumptions, which allow long-term forecasting.

Based on this model, we developed a business-as-usual scenario (BAU) of the road transport, i.e. passenger car transport sector in Brunei to the horizon of 2050 as a benchmark scenario to assess the impacts of penetration of new technologies in the passenger car fleet.

We define BAU as the scenario where the country's passenger car fleet would develop to the horizon of 2050 without any penetration of battery electric or fuel-cell hydrogen cars. This scenario means that up to 2050, there will be only two kinds of passenger cars based on fuel types: gasoline- and diesel-fuelled passenger cars.

The first new technology we analysed is the EV. We elaborated three EV scenarios representing certain penetration levels of full BEVs in the country's road passenger car fleet in 2017–2050.

The level of penetration is represented by the exogenously defined percentages of shares of BEV in the total number of passenger cars in Brunei in 2050. We assumed that there was no electric vehicle in the base year in all scenarios, i.e. 2017.

The three EV scenarios in Brunei are:

- EV20 – a scenario where battery electric cars would make 20% share of the total road passenger car fleet in 2050
- EV40 – a scenario where battery electric cars would make 40% share of the total road passenger car fleet in 2050
- EV60 – a scenario where battery electric cars would make 60% share of the total road passenger car fleet in 2050.

The second technology is the hydrogen-powered fuel cell (FC) vehicle. Three FC scenarios were elaborated to represent certain penetration levels of hydrogen-powered FC cars in the country's road passenger car fleet in 2017– 2050.

The same as the EV scenarios, the level of penetration is represented by the exogenously defined percentages of shares of FCs in the total number of road passenger cars in Brunei in 2050. In all scenarios, we assumed that there is no FC in 2017, the base year.

The three main FC scenarios in Brunei are:

- FC10 – a scenario where FC hydrogen cars would make 10% share of the total road passenger car in 2050
- FC20 – a scenario where FC hydrogen cars would make 20% share of the total road passenger car fleet in 2050
- FC30 – a scenario where FC hydrogen cars would make 30% share of the total road passenger car fleet in 2050.

To compare with the production of hydrogen from natural gas steam reforming without carbon capture and sequestration (CCS) – considered the most mature technology pathway of hydrogen production in Brunei – we also simulated two other variants: hydrogen production from natural gas steam reforming with CCS and from electrolysis.

2.3. Assumptions of the study

2.3.1. Population, GDP, and Power Generation Energy Mix

The population is expected to grow at 1.5% per year during the whole observation period. We used the projection of the International Monetary Fund (IMF, 2019) as our main source for GDP growth (Table 3.1). The annual growth rate decreases from 4.7% in 2017–2020, the base year's period, to around 2.1% in 2023–2050.

Table 3.1: Assumptions on GDP growth

Period	Annual Growth Rate, %
Up to 2020	4.7
2020 to 2021	3.6
2021 to 2022	3.5
2022 to 2023	2.4
2023 and beyond	2.1

Source: IMF (2019).

We assumed that natural gas–fired plants comprise 99% of the total electricity generation during the whole simulation period. The remaining 1% is composed of diesel-fired power plants and a negligible solar photovoltaic (PV) portion.

2.3.2. Hydrogen Production

Hydrogen can be produced from fossil-based options and renewable sources. Fossil-based options can include steam reforming of natural gas and coal gasification. These are thermochemical processes where the feedstock is processed at high temperatures in a gasification medium, such as air, oxygen, and/or steam to produce syngas. Those two options are mature technologies, but the implementation of carbon capture and storage (CCS) systems might be required reduce CO_2 emissions of both options.

Hydrogen can also be produced from renewable sources, such as wind power water electrolysis, steam reforming of biofuels, and biomass gasification.

Water electrolysis involves a process in which electricity is converted into chemical energy in the form of hydrogen with oxygen as a by-product. When using grid electricity, Brunei's electricity production mix becomes a crucial aspect. The possibility of using the electricity surplus from renewable power generation facilities, such as PV or hydropower plants to produce hydrogen through water electrolysis, should be pursued.

Hydrogen in Brunei is assumed to be uniquely produced from steam reforming based on the gas generated by Brunei LNG (liquefied natural gas's plant). The process is currently without CCS.

Citing various sources – Collodi et al. (2017), Keipi et al., (2018), Mondal and Chandran, (2014), Navas-Anguita et al. (2020) – we summarised the steam reforming process as follows: during the steam reforming of natural gas or renewable feedstock, steam and hydrocarbons are heated up to 800–1,000 °C to produce synthetic gas. Afterwards, the syngas stream undergoes a water gas shift process to increase the hydrogen content. In a subsequent step, hydrogen is separated and purified, e.g. through a pressure swing adsorption unit.

Navas-Anguita et al. (2020) estimated energy efficiency rates in various hydrogen production pathways. We extracted and analysed three pathways in this report (Table 3.2), i.e. steam reforming of natural gas with and without CCS and electrolysis with grid electricity.

Table 3.2: Energy Efficiency in Hydrogen Production

Study	2017–2020	2021–2029	2030–2050
Steam reforming of natural gas without CCS	76%	Interpolation	85%
Steam reforming of natural gas with CCS	65%	Interpolation	70%
Electrolysis	67%	Interpolation	85%

CCS = carbon capture and sequestration.
Source: Navas-Anguita et al. (2020).

2.3.3. Passenger Car Transport

The total number of passenger cars in the future is a key assumption that would determine energy consumption and the transport sector's profile. Forecasting the future number of passenger cars can estimated using Brunei's future car ownership rate, given the number of cars per 1,000 inhabitants. A usual method in estimating the car ownership rate is using the car ownership model developed, for example, by Dargay et al. (2007). This model employs an S-shaped function, i.e. the Gompertz function, to estimate the relationship between vehicle ownership and per-capita GDP.

Equation (1)… $V_{year} = \gamma . e^{\alpha . e^{\beta . GDPCAP_{year}}}$

where

V_{year} = long-run equilibrium of car ownership rate (cars per 1,000 inhabitants at purchasing power parity)
γ = saturation level (cars per 1,000 inhabitants)
$GDPCAP_{year}$ = GDP per capita (expressed in constant local current unit (LCU) of 2018)
α, β = parameters defining the shape, or curvature, of the function

However, the GDP per capita of Brunei had been decreasing from 2008 to 2018 by an average annual rate of 1.3%, whilst the car ownership rate had been increasing from around 542 vehicles per 1,000 inhabitants in 2008 to around 658 vehicles per 1,000 inhabitants, i.e. an average annual growth rate of around 2.1%.

The GDP per capita cannot be used as the only dependent variable to estimate the car ownership rate. We incorporated time, i.e. year, as another dependent variable, which signifies the inclusion of other factors not explicitly described by the equation, i.e. lifestyle, urbanisation, road infrastructure development, etc. The equation is given as follows, where δ is the additional parameter that defines the function's shape or curvature.

Equation (2)… $V_{year} = \frac{\gamma}{1+\alpha . e^{\beta * year} . GDPCAP_{year}{}^{\delta}}$

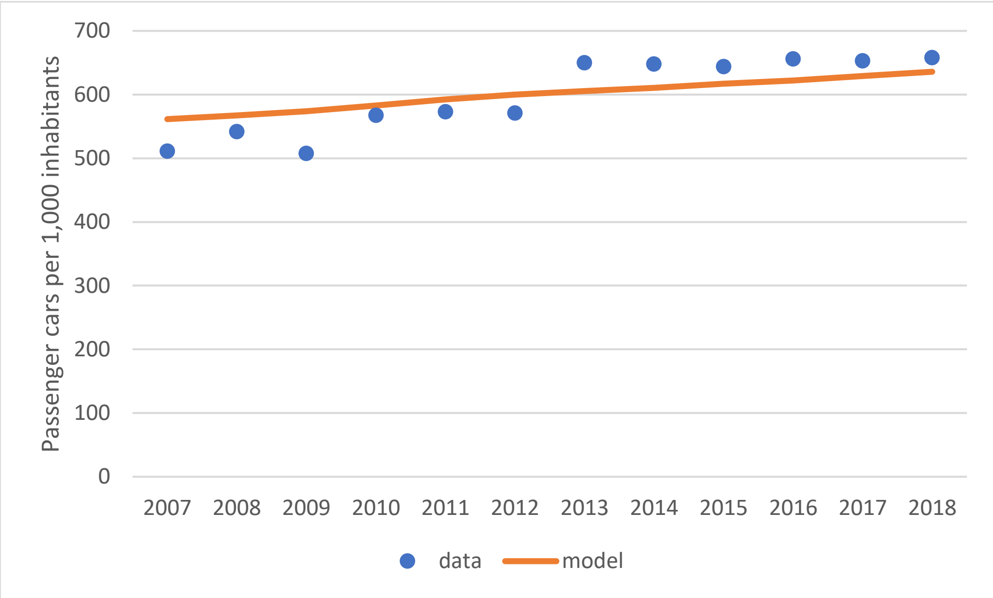
Using car ownership, GDP, and population data from 2007 to 2018, we estimated the parameters of equation (2) with the coefficient of determination (r2) of 0.602 in Table 3.3.

Table 3.3: Estimated Parameters of Equation (2)

Parameters	Estimated Value
γ	844
Ln(α)	93.96
β	-0.045
δ	-0.4

Source: Authors' calculation.

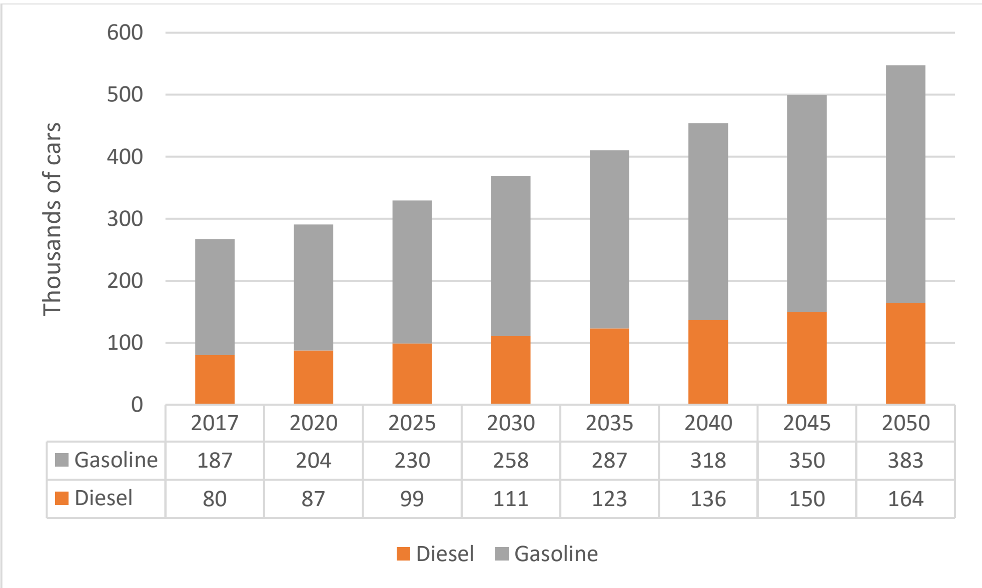
Figure 3.1: Data and Modelled Car Ownership Rate



Source: Authors' calculation.

Combined with Brunei's estimated future population, we obtained the estimated number of cars in use (Figure 3.2). We expected the number of cars in use or active would grow from 270,000 to 370,000 by 2030, 455 (2040), and 550 (2050).

Figure 3.2: Estimated Number of Passenger Cars in Use



	2017	2020	2025	2030	2035	2040	2045	2050
Gasoline	187	204	230	258	287	318	350	383
Diesel	80	87	99	111	123	136	150	164

Source: Authors' calculation.

Tables 3.4 and 3.5 show our assumptions in the electric car and hydrogen-powered FC scenarios. We assume the fuel-cell efficiency of FCEVs of 1.1 MJ/km or 3.27 km/kWh. This is in line with the specification of the compact hydrogen-powered fuel cell Toyota Mirai passenger car model FCA110 of the year 2015 whose specification is given by Toyota Europe (2015).

Table 3.4: Passenger Car–Related Assumptions for Electric Car Scenarios

Variable	Description	Unit	2017	2018–2049	2050	Source
TOTCAR	Total number of cars	million cars	0.29	See equation (2) and Table 3.3		Authors' estimate
DSLCAR	ICE- diesel cars	million cars	0.09	$(TOTCAR_{year} - ELECAR_{year}).0.7$		Authors' estimate
GSLCAR	ICE - gasoline cars	million cars	0.2	$(TOTCAR_{year} - ELECAR_{year}).0.3$		Authors' estimate
EVCARSH	Share of BEV based on scenarios	%	0	$\frac{x.(year - 2017)}{(2050 - 2017)}$	x	Authors' assumption
ELECAR	Number of BEVs	million cars	0	$TOTCAR_{year}.EVCARSH_{year}$		Authors' estimate
FE	Fuel economy of ICE cars	km/l	12.7			Authors' estimate
BATEFF	BEV battery efficiency	km/kWh	5			Authors' estimate
KMYEAR	Average distance travelled (km/ year)	km	24000			Authors' estimate

ICE = internal combustion engine.
Source: Author.

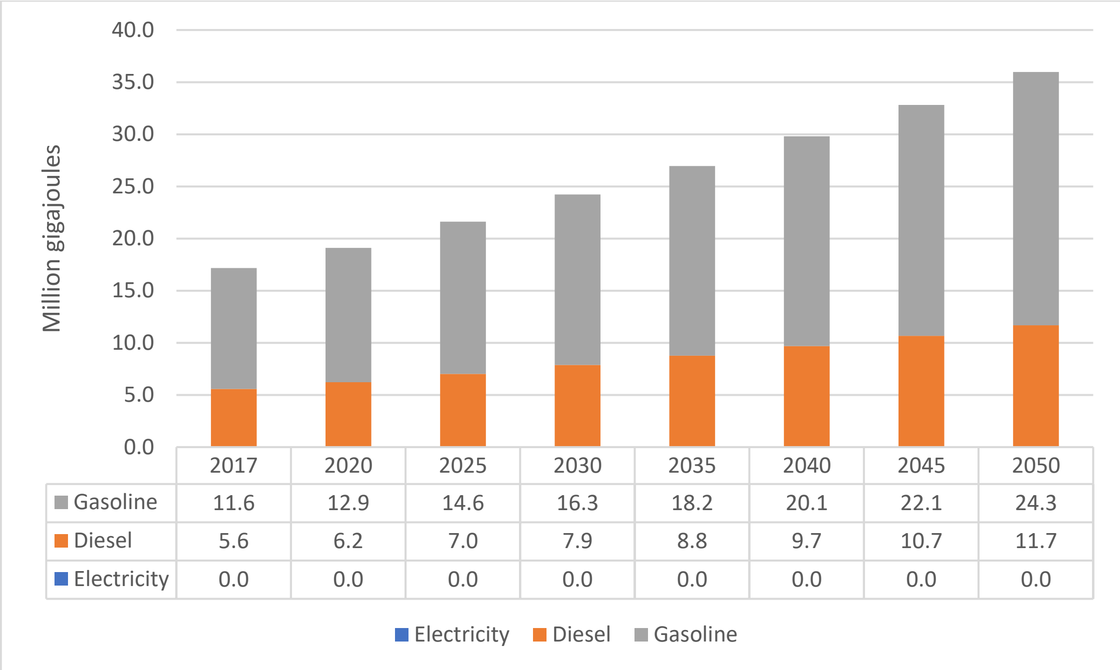
Table 3.5: Passenger Car–Related Assumptions for Hydrogen-Powered Fuel Cell Car Scenarios

Variable	Description	Unit	2017	2018–2049	2050	Source
TOTCAR	Total number of cars	million cars	0.29	See equation (2) and Table 3.4		Authors' estimate
DSLCAR	ICE- diesel cars	million cars	0.09	$(TOTCAR_{year} - FCEVCAR_{year}).0.7$		Authors' estimate
GSLCAR	ICE-gasoline cars	million cars	0.2	$(TOTCAR_{year} - FCEVCAR_{year}).0.3$		Authors' estimate
FCEVCARSH	Share of FCEV based on scenarios	%	0	$\frac{x.(year-2017)}{(2050-2017)}$	x	Authors' assumption
FCEVCAR	Number of FCEVs	million cars	0	$TOTCAR_{year}.FCEVCARSH_{year}$		
FE	Fuel economy of ICE cars	km/l	12.7			Authors' estimate
FCEFF	Fuel cell efficiency	km/kWh	3.27			Toyota Motor Europe (2015)
KMYEAR	Average distance travelled (km/year)	km	24000			Authors' estimate

ICE = internal combustion engine.
Source: Author.

We can expect that in BAU, between 2017 and 2050, energy demand from passenger car transport in Brunei would increase by around 12% per year from about 17 million gigajoules (GJ) in 2017 to approximately 36 million GJ in 2050, an increase of around 11% annually. Gasoline–diesel consumption ratio would be around 2:1, and full BEVs are assumed to enter the road passenger car fleet during the whole simulation period.

Figure 3.3: Energy Consumption of Passenger Cars – Business-As-Usual Scenario



	2017	2020	2025	2030	2035	2040	2045	2050
Gasoline	11.6	12.9	14.6	16.3	18.2	20.1	22.1	24.3
Diesel	5.6	6.2	7.0	7.9	8.8	9.7	10.7	11.7
Electricity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: LEAP model running results (2020).

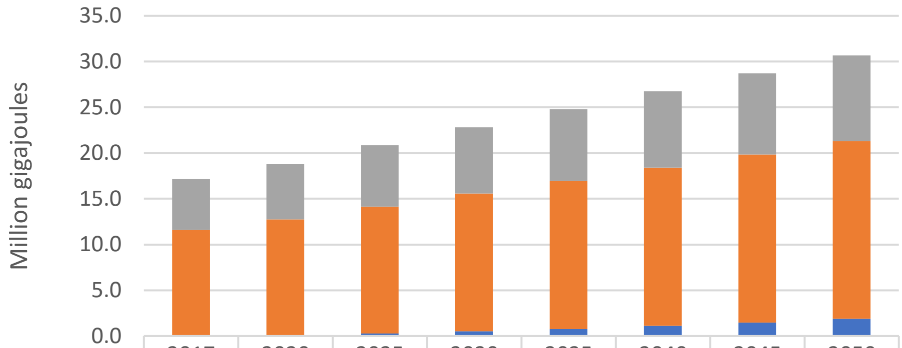
2.4. Results

The following subsections discuss the LEAP model running results of the EV and FCEV scenarios where hydrogen is produced from natural gas steam reforming without CCS and where hydrogen is produced from other pathways, i.e. natural gas reforming with CCS and electrolysis.

2.4.1. Electric Car (EV) Scenarios

Figure 3.4 shows that having BEVs composing 20% of the passenger car fleet by 2050 would reduce the total energy consumption in 2050 by around 5 million GJ compared to BAU. The yearly growth rate of total energy consumption would be reduced from 11% in BAU to about 8.5%.

Figure 3.4: Energy Consumption of Passenger Cars – EV20 Scenario



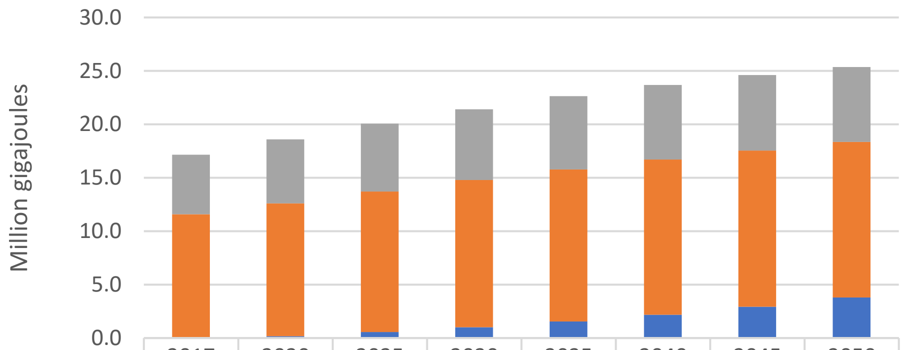
	2017	2020	2025	2030	2035	2040	2045	2050
Diesel	5.6	6.1	6.7	7.3	7.8	8.3	8.9	9.4
Gasoline	11.6	12.6	13.9	15.1	16.2	17.3	18.4	19.4
Electricity	0.0	0.1	0.3	0.5	0.8	1.1	1.5	1.9

Electricity Gasoline Diesel

Source: LEAP model running results (2020).

Having full BEVs comprising 40% of the total passenger cars (Figure 3.5) should reduce the total energy demand by 2050 to about 25 million GJ. The yearly growth rate of energy demand is around 5.3%. It is interesting to note that starting at around the year 2045, gasoline and diesel fuel demand should reach stagnation.

Figure 3.5: Energy Consumption of Passenger Cars – EV40 Scenario



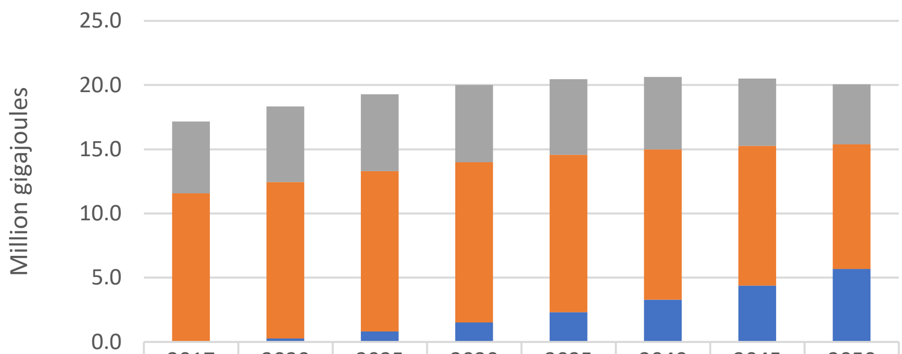
	2017	2020	2025	2030	2035	2040	2045	2050
Diesel	5.6	6.0	6.4	6.6	6.9	7.0	7.1	7.0
Gasoline	11.6	12.4	13.2	13.8	14.2	14.5	14.6	14.6
Electricity	0.0	0.2	0.6	1.0	1.5	2.2	2.9	3.8

Electricity Gasoline Diesel

Source: LEAP model running results (2020).

Finally, having 60% BEVs amongst the passenger car fleet in 2050 would reduce the total energy demand to around 20 million MJ in 2050 (Figure 3.6). Total energy demand would reach its peak at about 21 million MJ somewhere between 2035 and 2040. Beyond that period, total energy demand would be decreasing.

Figure 3.6: Consumption of Passenger Cars – EV60 Scenario



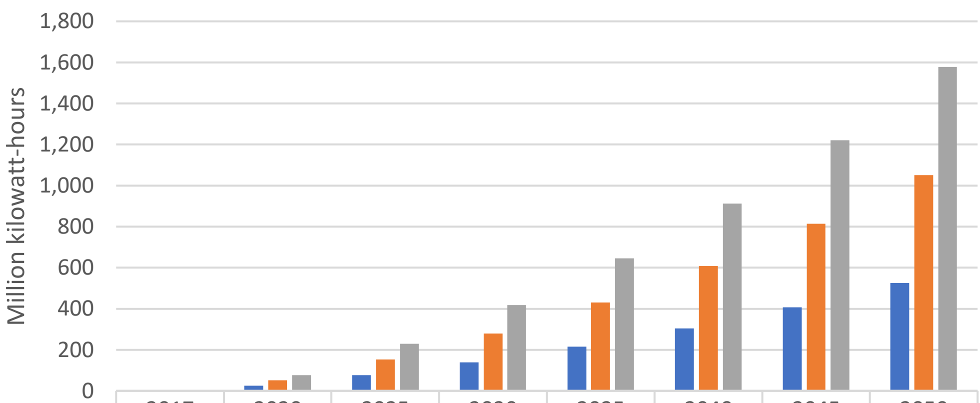
	2017	2020	2025	2030	2035	2040	2045	2050
Diesel	5.6	5.9	6.0	6.0	5.9	5.6	5.2	4.7
Gasoline	11.6	12.2	12.5	12.5	12.2	11.7	10.9	9.7
Electricity	0.0	0.3	0.8	1.5	2.3	3.3	4.4	5.7

Electricity Gasoline Diesel

Source: LEAP model running results (2020).

Compared to BAU, in 2050, EV scenarios would consume approximately 526, 1,052, and 1,577 million kWh of additional generated electricity, respectively, in EV20, EV40, and EV60 scenarios (Figure 3.7). If the total generated electricity in Brunei Darussalam in BAU grows from 3,700 million kWh in 2017 to 5,600 million kWh in 2050, the electric demand of EV scenarios in 2050 would correspond to an additional increase of consecutively 9%, 19%, and 28% compared to BAU.

Figure 3.7: Electric Energy Needed in Electric Car Scenarios

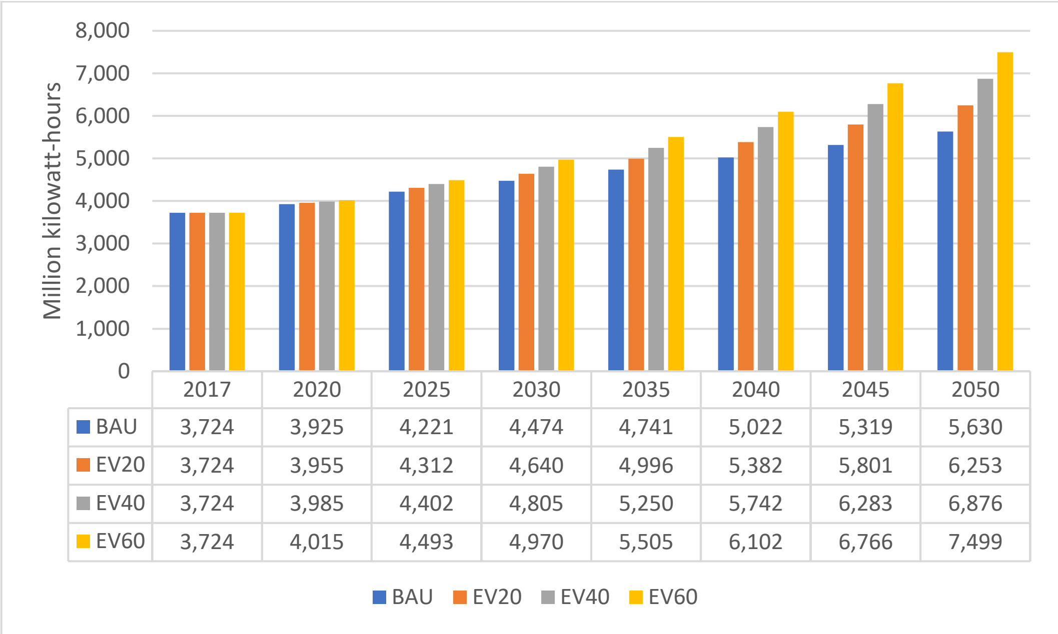


	2017	2020	2025	2030	2035	2040	2045	2050
EV20	0	25	77	140	215	304	407	526
EV40	0	51	153	279	430	608	814	1,052
EV60	0	76	230	419	645	912	1,221	1,577

EV20 EV40 EV60

Source: LEAP model running results (2020).

Figure 3.8: Generated Electricity – Electric Cars Scenarios

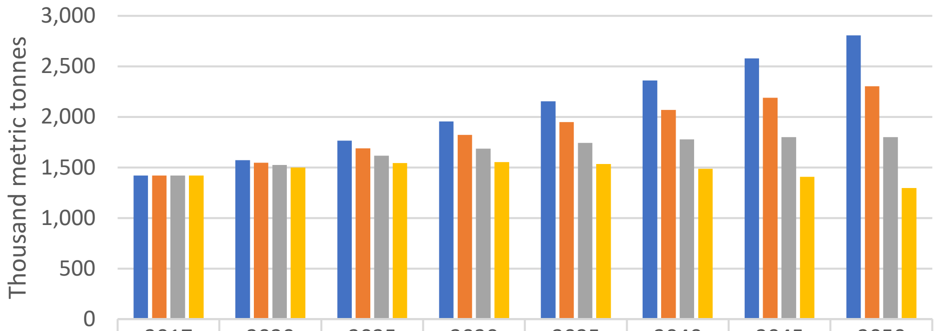


Source: LEAP model running results (2020).

The penetration of BEVs should affect CO_2 emissions in two sectors: passenger car transport and power generation. In the passenger car transport sector, the penetration of BEVs means shifting from conventional fuels – gasoline and diesel – to electricity, which should reduce CO_2 emitted by passenger cars.

We can expect CO_2 emissions from road passenger cars in Brunei in BAU to double from around 1.4 million tonnes of CO_2 in 2017 to about 2.8 million tonnes in 2050, a 33-year period. Compared to BAU, the three electric-car scenarios – EV20, EV40, and EV60 – should reduce CO_2 emissions from passenger cars by 2050 by 18%, 36%, and 54%, respectively. The effect of EV60 scenario would be significant as it would cause CO_2 emission from passenger cars to peak somewhere between 2040 and 2045.

Figure 3.9: CO_2 Emissions from Passenger Cars – Electric Cars Scenarios



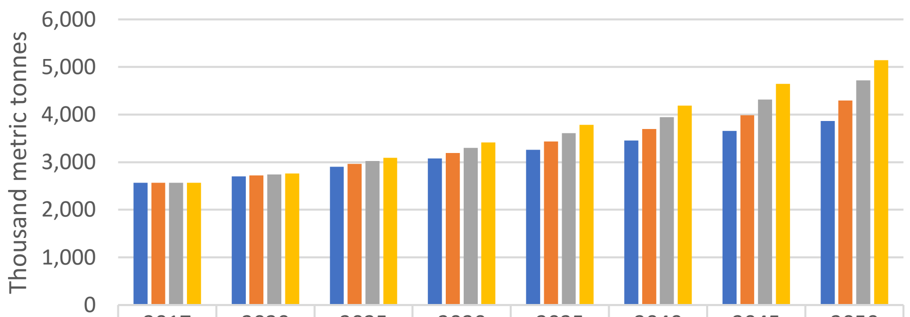
	2017	2020	2025	2030	2035	2040	2045	2050
BAU	1,421	1,572	1,764	1,955	2,154	2,362	2,580	2,809
EV20	1,421	1,548	1,691	1,821	1,948	2,071	2,190	2,304
EV40	1,421	1,524	1,618	1,688	1,742	1,779	1,799	1,800
EV60	1,421	1,499	1,544	1,554	1,536	1,488	1,409	1,296

BAU EV20 EV40 EV60

Source: LEAP model running results (2020).

Having BEVs in the passenger car fleet also means that additional electric power needs to be generated. Assuming that Brunei's electricity would be produced almost uniquely in the gas-fired power plants, this additional generated power would mean an increase in CO_2 emissions. Figure 3.10 shows that the higher the number of BEVs in the scenarios, the higher the CO_2 emitted in the power plants. In BAU, we expect that CO_2 emissions would increase from 2.6 million tonnes CO_2 in 2017 to reach 3.9 million tonnes CO_2 in 2050. Compared to BAU, the EV20, EV40, and EV60 scenarios should increase the CO_2 emission in 2050 by 11%, 22%, and 33%, respectively. In EV60, we can expect that CO_2 emission from power generation would double from 2,600 million tonnes CO_2 in 2017 to 5,200 million tonnes CO_2 in 2050.

Figure 3.10: CO_2 Emissions from Electricity Generation – Electric Cars Scenarios



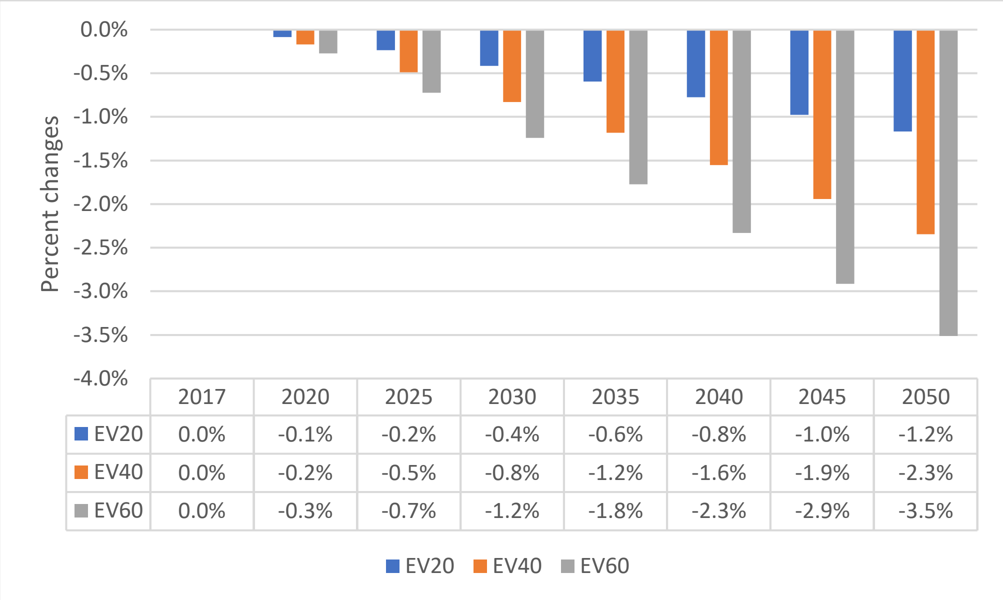
	2017	2020	2025	2030	2035	2040	2045	2050
BAU	2,568	2,702	2,904	3,078	3,260	3,452	3,656	3,867
EV20	2,568	2,723	2,966	3,191	3,434	3,699	3,985	4,294
EV40	2,568	2,743	3,028	3,304	3,609	3,945	4,315	4,719
EV60	2,568	2,763	3,091	3,417	3,783	4,191	4,645	5,146

BAU EV20 EV40 EV60

Source: LEAP model running results (2020).

Considering the passenger car and power generation sectors, BEVs in Brunei Darussalam should contribute to reducing CO_2 emissions. The EV60 scenario should reduce CO_2 the most, i.e. we can expect that in 2050 it would reduce the total CO_2 emission by 3.5% whilst EV20 and EV40 would reduce emissions by 1.2% and 2.3%, respectively (Figure 3.11). As shown previously in the discussion related to Figure 3.10, these limited impacts on CO_2 reduction by BEV penetration are caused mainly by the energy mix in Brunei's power generation, which is based almost solely on natural gas.

Figure 3.11: Changes in Total CO_2 Emissions in Electric Cars Scenarios Relative to BAU (%)



	2017	2020	2025	2030	2035	2040	2045	2050
EV20	0.0%	-0.1%	-0.2%	-0.4%	-0.6%	-0.8%	-1.0%	-1.2%
EV40	0.0%	-0.2%	-0.5%	-0.8%	-1.2%	-1.6%	-1.9%	-2.3%
EV60	0.0%	-0.3%	-0.7%	-1.2%	-1.8%	-2.3%	-2.9%	-3.5%

Source: LEAP model running results (2020).

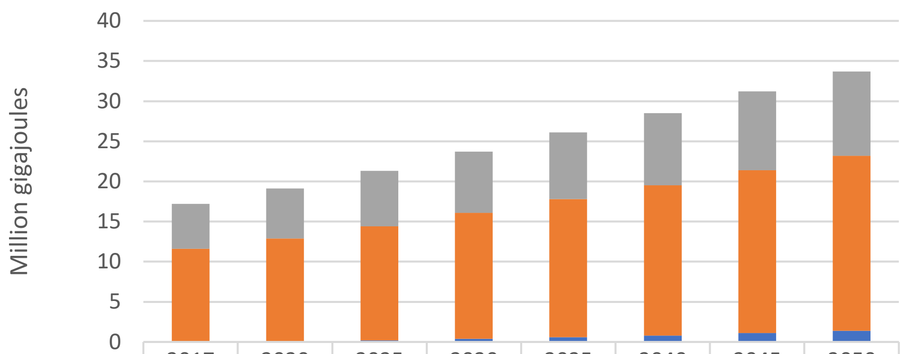
2.4.2. Hydrogen-Powered Fuel Cell Car Scenarios

a) Hydrogen production: steam reforming without CCS

Currently, natural gas steam reforming without CCS is the most feasible pathway of producing hydrogen in Brunei. In this section, we discuss the results of the different scenarios of having FCs in the country's passenger car fleet.

With 10% FCs comprising the total passenger cars by 2050, the FC10 scenario should reduce total energy demand from passenger car fleet by 6%, i.e. a reduction from 36 million GJ in BAU to 33.8 million GJ in the FC10 scenario (Figure 3.12). The reduction in total energy demand from the passenger car fleet would decrease with the increasing rate of FC penetration, i.e. the FC20 and FC30 scenarios should reduce the energy demand of the total passenger car fleet in 2050 by around 12% (Figure 3.13) and 18% (Figure 3.14) consecutively.

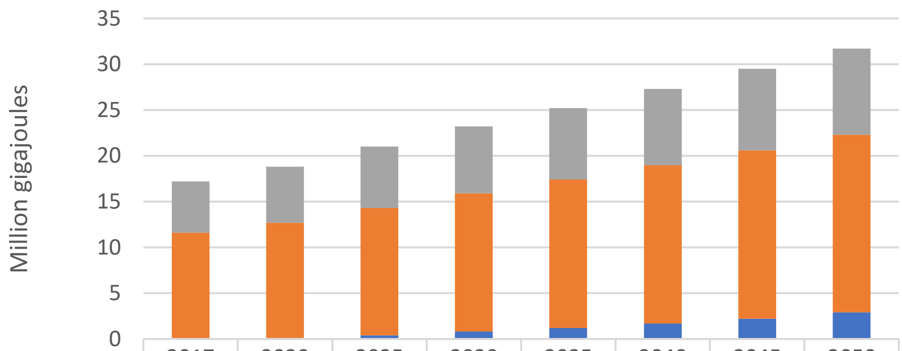
Figure 3.12: Energy Consumption of Passenger Cars – FC10 Scenario



	2017	2020	2025	2030	2035	2040	2045	2050
Diesel	5.6	6.2	6.9	7.6	8.3	9	9.8	10.5
Gasoline	11.6	12.8	14.2	15.7	17.2	18.7	20.3	21.8
Hydrogen	0	0.1	0.2	0.4	0.6	0.8	1.1	1.4

Source: LEAP model running results (2020).

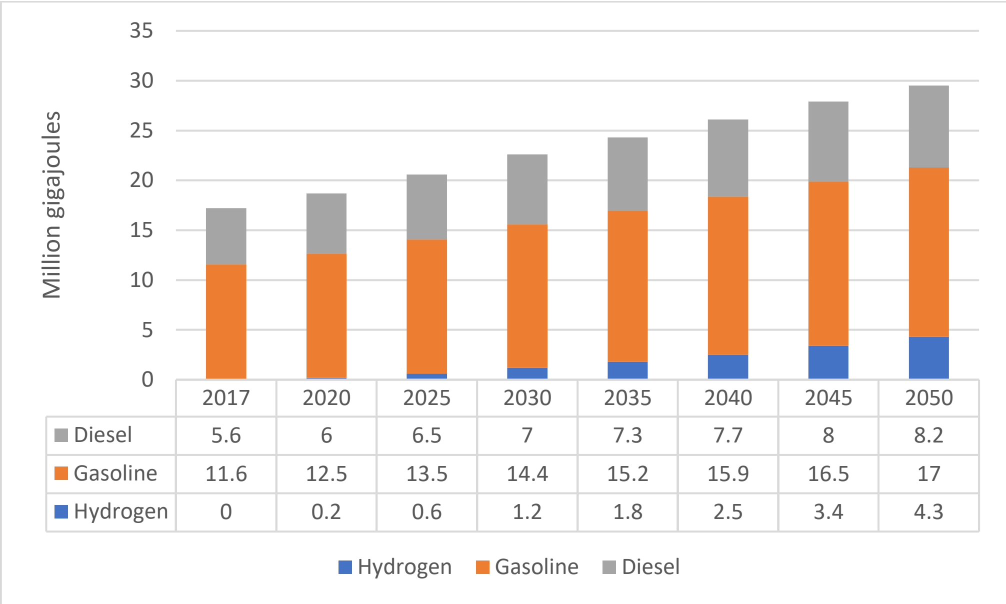
Figure 3.13: Energy Consumption of Passenger Cars – FC20 Scenario



	2017	2020	2025	2030	2035	2040	2045	2050
Diesel	5.6	6.1	6.7	7.3	7.8	8.3	8.9	9.4
Gasoline	11.6	12.6	13.9	15.1	16.2	17.3	18.4	19.4
Hydrogen	0	0.1	0.4	0.8	1.2	1.7	2.2	2.9

Source: LEAP model running results (2020).

Figure 3.14: Energy Consumption of Passenger Cars – FC30 Scenario

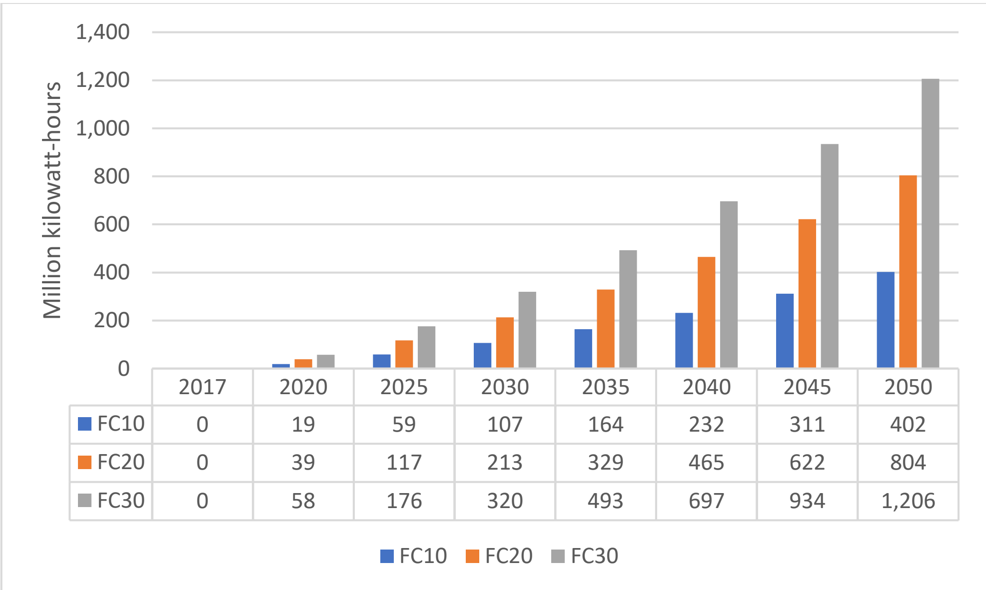


	2017	2020	2025	2030	2035	2040	2045	2050
Diesel	5.6	6	6.5	7	7.3	7.7	8	8.2
Gasoline	11.6	12.5	13.5	14.4	15.2	15.9	16.5	17
Hydrogen	0	0.2	0.6	1.2	1.8	2.5	3.4	4.3

Source: LEAP model running results (2020).

Figure 3.15 shows the hydrogen that needs to be produced in the country to meet the hydrogen demand in FC scenarios. In 2050, the FC10 scenario would need about 400 GWh of hydrogen; FC20, about 800 GWh; and FC30, about 1,200 GWh of hydrogen.

Figure 3.15: Produced Hydrogen – Fuel-Cell Hydrogen Scenarios

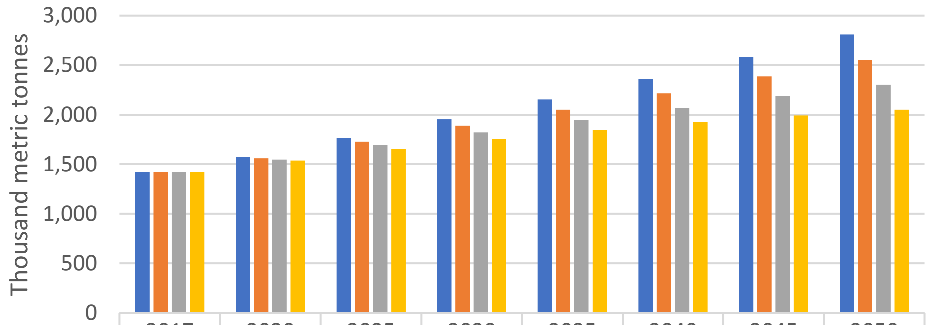


	2017	2020	2025	2030	2035	2040	2045	2050
FC10	0	19	59	107	164	232	311	402
FC20	0	39	117	213	329	465	622	804
FC30	0	58	176	320	493	697	934	1,206

Source: LEAP model running results (2020).

Shifting from gasoline- and diesel-fuelled passenger cars to fuel-cell passenger cars would reduce CO_2 emission of the total fleet of passenger cars. In 2050, the reductions from the three scenarios compared to BAU would be 9%, 18%, and 27%, respectively, from the FC10, FC20, and FC30 scenarios (Figure 3.16).

Figure 3.16: CO_2 Emissions of Passenger Car Transport – Fuel-Cell Hydrogen Cars Scenarios



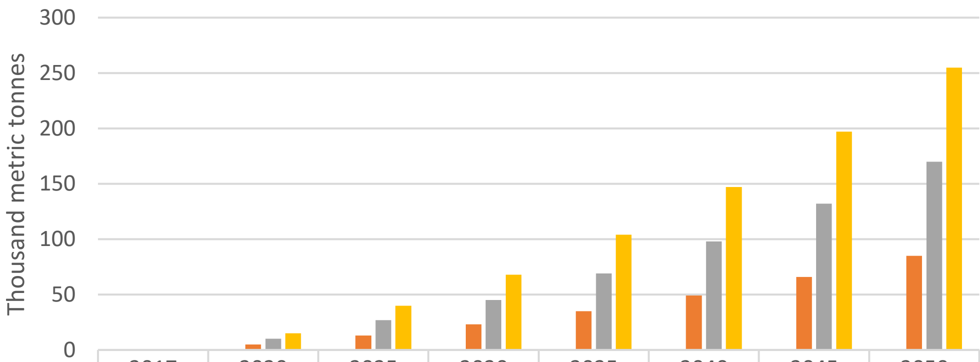
	2017	2020	2025	2030	2035	2040	2045	2050
BAU	1,421	1,572	1,764	1,955	2,154	2,362	2,580	2,809
FC10	1,421	1,560	1,728	1,888	2,051	2,216	2,385	2,556
FC20	1,421	1,548	1,691	1,821	1,948	2,071	2,190	2,304
FC30	1,421	1,536	1,654	1,755	1,845	1,925	1,994	2,052

BAU FC10 FC20 FC30

Source: LEAP model running results (2020).

At the same time, producing hydrogen from natural gas steam reforming without CCS would emit CO_2. In 2050, for example, we can expect that this hydrogen production would bring 85 thousand, 170 thousand, and 255 thousand metric tonnes CO_2 from the FC10, F20, and FC30 scenarios, respectively (Figure 3.17).

Figure 3.17: CO_2 Emissions from Hydrogen Production – Natural Gas Steam Reforming without CCS – Hydrogen-Powered Fuel-Cell Car Scenarios



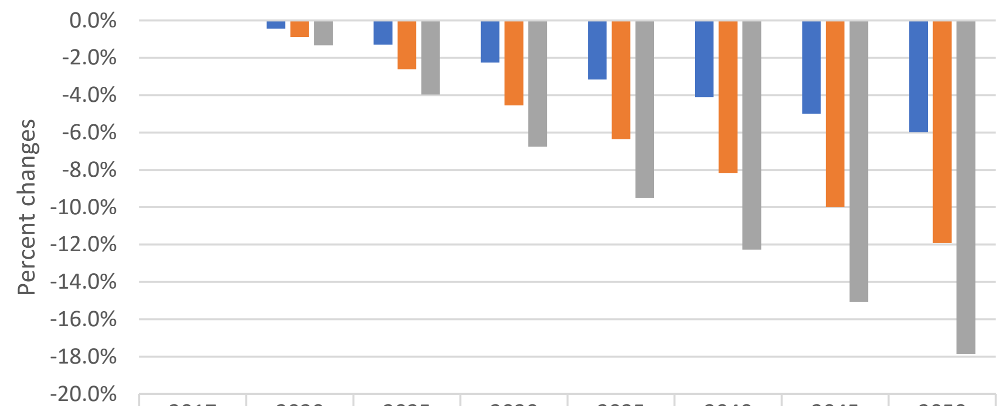
	2017	2020	2025	2030	2035	2040	2045	2050
BAU	0	0	0	0	0	0	0	0
FC10	0	5	13	23	35	49	66	85
FC20	0	10	27	45	69	98	132	170
FC30	0	15	40	68	104	147	197	255

BAU FC10 FC20 FC30

Source: LEAP model running results (2020).

FC penetration in the passenger car fleet in Brunei should overall reduce CO_2 emissions. In 2050, we can expect that, compared to BAU, the reduction rate would be around 6%, 12%, and 18% from the FC10, F20, and FC30 scenarios, respectively. These CO_2 emission reduction effects are higher than those from the BEV scenarios presented in Section 3.2.4.1.

Figure 3.18: Changes (%) in Total CO_2 Emissions in Hydrogen-Powered Fuel-Cell Car Scenarios vis-à-vis BAU – Hydrogen Produced from Natural Gas Steam Reforming without CCS



	2017	2020	2025	2030	2035	2040	2045	2050
FC10	0.0%	-0.4%	-1.3%	-2.3%	-3.2%	-4.1%	-5.0%	-6.0%
FC20	0.0%	-0.9%	-2.6%	-4.6%	-6.4%	-8.2%	-10.0%	-11.9%
FC30	0.0%	-1.3%	-4.0%	-6.8%	-9.5%	-12.3%	-15.1%	-17.9%

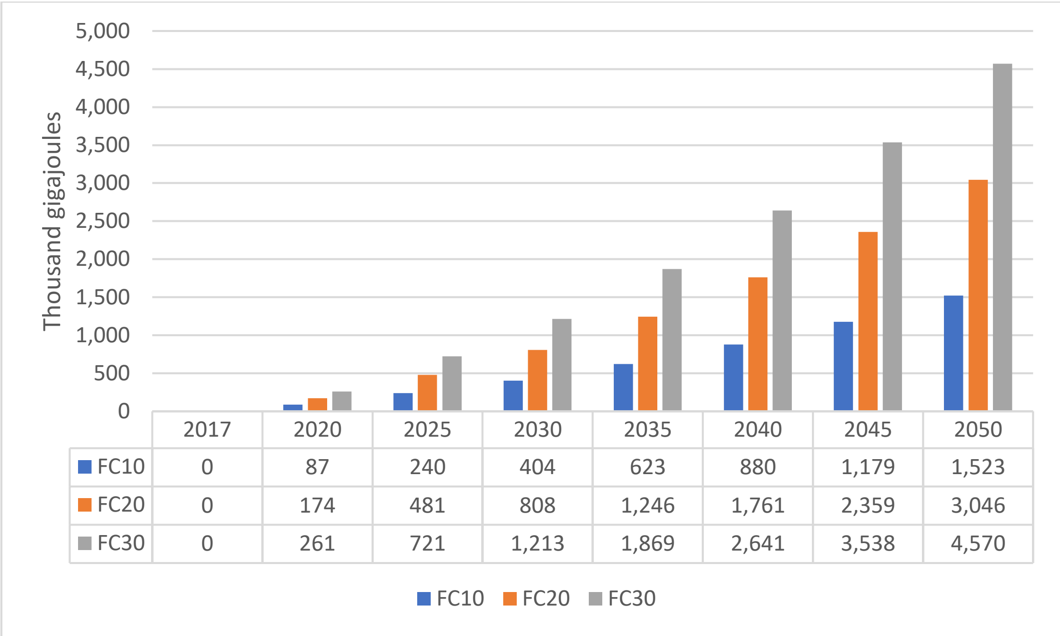
Source: LEAP model running results (2020).

b) **Other pathways of hydrogen production: steam reforming with CCS and electrolysis**

Apart from producing hydrogen from natural gas steam reforming without CCS, we also analysed the impacts of producing hydrogen using other pathways, i.e. natural gas steam reforming with CCS and electrolysis. This section discussed the energy needed to produce hydrogen and CO_2 emissions from the different hydrogen production pathways.

Figures 3.19 and 3.20 show the total energy input needed to produce hydrogen from steam reforming of natural gas consecutively without and with CCS. Hydrogen production via steam reforming with CCS needs more natural gas than without CCS, following the assumption on efficiency as explained in Section 1.8.5. That is, the process with CCS needed 20% more natural gas in 2017 than that without CCS and around 27% more in 2030 onwards.

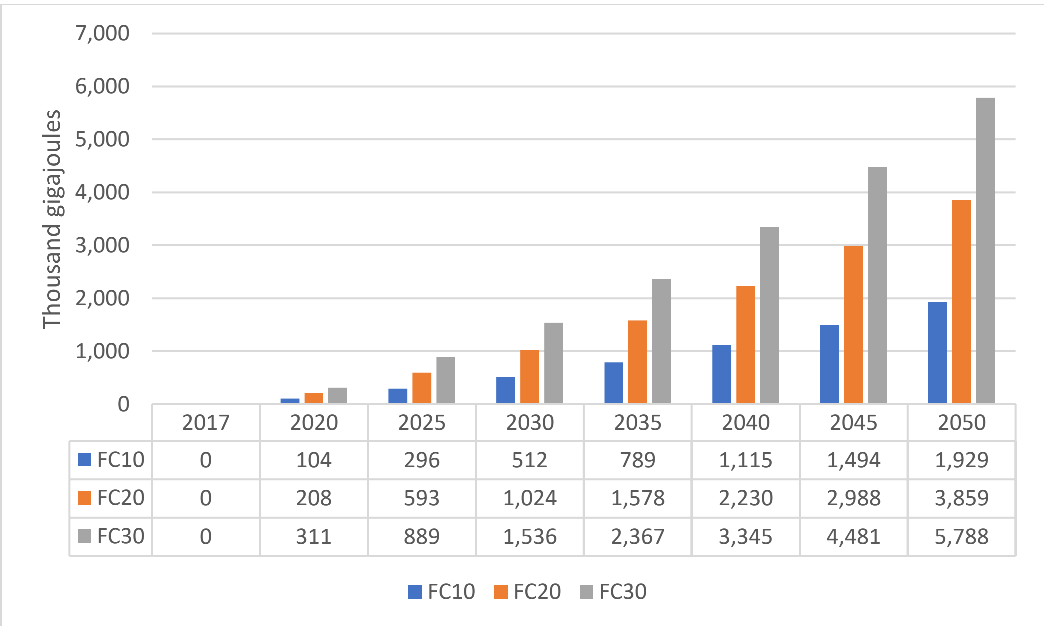
Figure 3.19: Natural Gas Input to Produce Hydrogen from Natural Gas Steam Reforming without CCS



	2017	2020	2025	2030	2035	2040	2045	2050
FC10	0	87	240	404	623	880	1,179	1,523
FC20	0	174	481	808	1,246	1,761	2,359	3,046
FC30	0	261	721	1,213	1,869	2,641	3,538	4,570

CCS = carbon capture and sequestration.
Source: LEAP model running results (2020).

Figure 3.20: Natural Gas Input to Produce Hydrogen from Natural Gas Steam Reforming with CCS

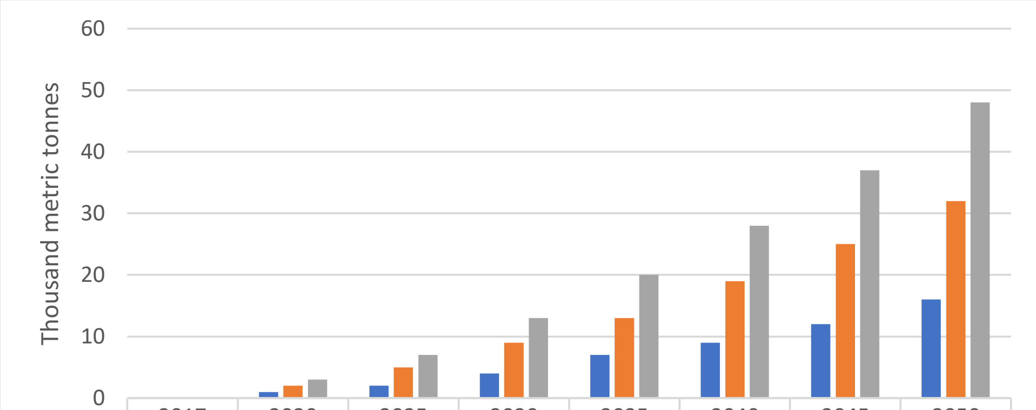


	2017	2020	2025	2030	2035	2040	2045	2050
FC10	0	104	296	512	789	1,115	1,494	1,929
FC20	0	208	593	1,024	1,578	2,230	2,988	3,859
FC30	0	311	889	1,536	2,367	3,345	4,481	5,788

CCS = carbon capture and sequestration.
Source: LEAP model running results (2020).

Whilst it needs more natural gas feedstock, hydrogen production from natural gas steam reforming with CCS emits significantly lower CO_2 (Figure 3.21). In FC 30, the most advanced FC scenario, we can expect this hydrogen production pathway to emit not more than 48 thousand metric tonnes CO_2 in 2050. This is less than one-fifth (or 255 thousand metric tonnes) of CO_2 emission from hydrogen production from natural gas reforming with CCS (Figure 3.17).

Figure 3.21: CO_2 Emission from Hydrogen Production from Methane Steam Reforming with CCS – Fuel-Cell Car Scenarios



	2017	2020	2025	2030	2035	2040	2045	2050
FC10	0	1	2	4	7	9	12	16
FC20	0	2	5	9	13	19	25	32
FC30	0	3	7	13	20	28	37	48

CCS = carbon capture and sequestration.
Source: LEAP model running results (2020).

Hydrogen can also be produced by water electrolysis, i.e. splitting water into hydrogen and oxygen using electric energy. We can usually differentiate this pathway into two methods based on the electricity sources used in the process. The first is from renewable energy, such as wind and solar, and the second is from grid power.

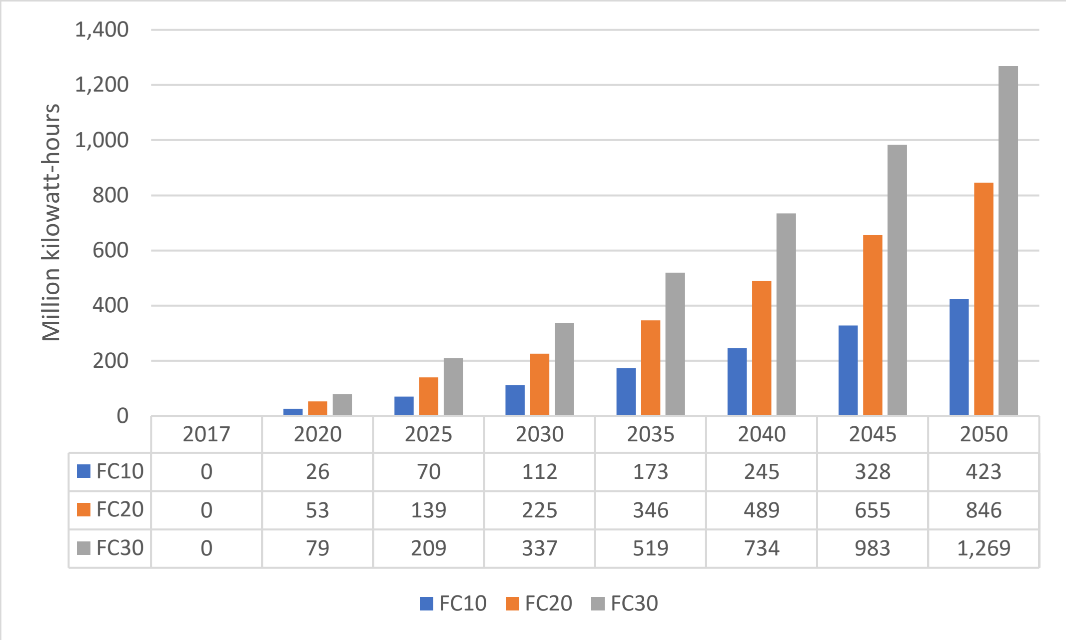
Producing hydrogen from electrolysis emits practically no CO_2. However, as the installed capacity of solar and wind power plants is limited in Brunei, this pathway is currently not feasible.

Figure 3.22 shows the additional grid electricity needed to produce hydrogen to meet the needs of FC scenarios. As electrolysis has low efficiency (see Section 3.2.3), FC scenarios would require more electricity than EV scenarios. For example, the FC20 scenario would need at least 60% more electricity than EV20 (see Figure 3.7).

The grid electricity–based electrolysis pathway also emits more CO_2 than the other hydrogen production pathways. As Figure 3.23 shows, in 2050, CO_2 emission from hydrogen production using grid electricity–based electrolysis is four times higher than that of steam reforming without CCS.

Considering both electricity needs and CO_2 emission, we can consider hydrogen production from grid electricity–based electrolysis a non-reasonable pathway of hydrogen production.

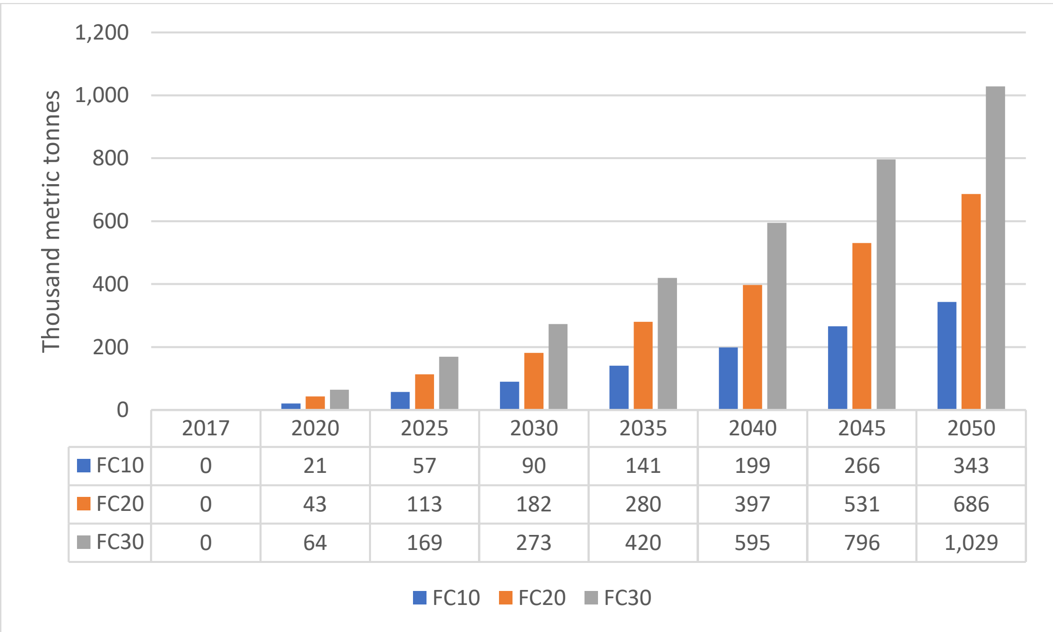
Figure 3.22: Grid Electricity Needed to Produce Hydrogen by Electrolysis



	2017	2020	2025	2030	2035	2040	2045	2050
FC10	0	26	70	112	173	245	328	423
FC20	0	53	139	225	346	489	655	846
FC30	0	79	209	337	519	734	983	1,269

Source: LEAP model running results.

Figure 3.23: CO_2 Emission from Hydrogen Production from Grid Electricity–Based Electrolysis – Fuel-Cell Car Scenarios



	2017	2020	2025	2030	2035	2040	2045	2050
FC10	0	21	57	90	141	199	266	343
FC20	0	43	113	182	280	397	531	686
FC30	0	64	169	273	420	595	796	1,029

Source: LEAP model running results.

2.5. Elements of conclusion

Both electric- and hydrogen-powered FCs are more energy efficient than conventional internal combustion engine cars. Both technologies should reduce CO_2 emissions in the transport and power generation sectors and hydrogen production.

The effects of the penetration of hydrogen-powered FCs on CO_2 emissions depend on how hydrogen is produced. Using natural gas steam reforming–based hydrogen, with or without CCS, to feed FCs can potentially reduce the total CO_2 emissions more than the penetration of electric cars. The best effect of hydrogen-powered FC penetration on CO_2 emissions would be obtained when the hydrogen is produced by water electrolysis with renewable energy source–based electric power. The effect would be negative if hydrogen is produced by electrolysis with electric power coming from the grid.

A massive implementation of hydrogen-powered FCs will imply changes in the development of hydrogen production technologies according to the techno-economic and environmental features, which must be implemented in the model.

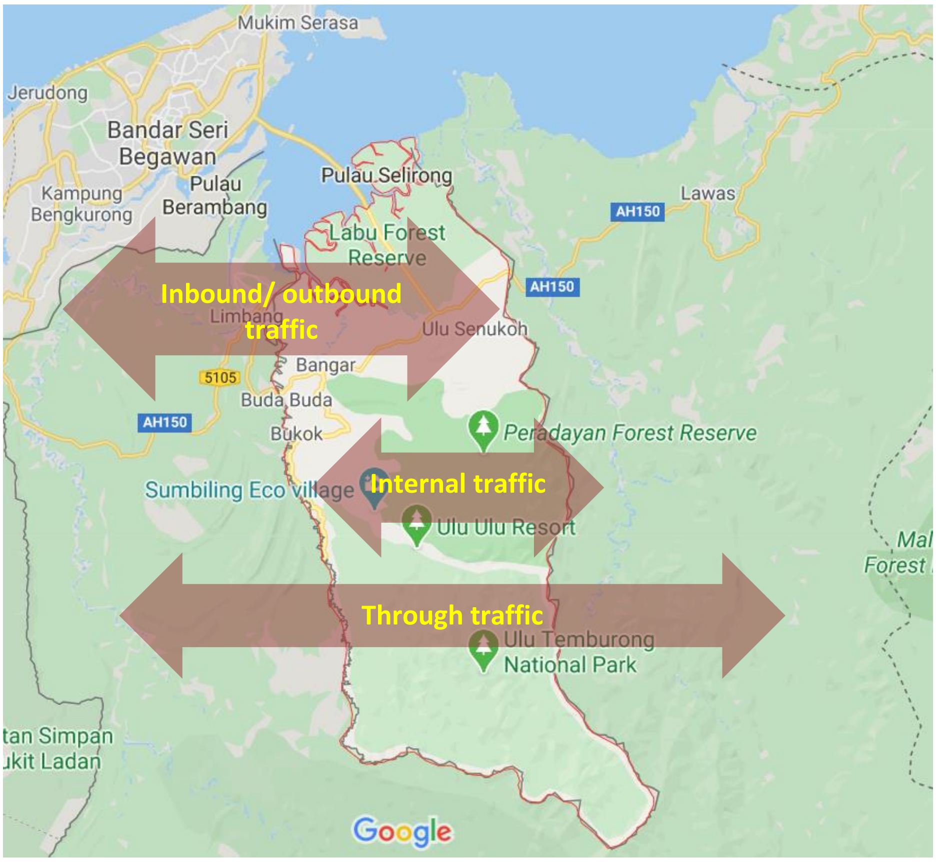
3. Low-Carbon Traffic System for Temburong District

3.1. Framework for analysis

Considering the growth of the district that includes economic and demographic aspects, activities, and land-use development up to 2030, the study proposed a mobility network for the district whose principles could be grouped into three trip categories:

- *Inbound/outbound traffic*: Tourists from BSB would visit Temburong via hydrogen-powered mass-transit bus through Temburong Bridge.
- *Internal traffic*: Tourists travel around Temburong district in non-carbon vehicles such as community buses, boats, and taxis.
- *Passing through traffic*: In the future, only non-carbon cars will be permitted to drive in Temburong district. This also aims to control the traffic volume (internal-combustion engine cars, buses, and trucks) between Sabah and Sarawak State in Malaysia, passing through Temburong. Brunei is located in the middle of the main road traffic corridor connecting the two Malaysian states.

Figure 3.24: Three Traffic Flow Categories



Source: Google Maps with Author's elaboration.

We included several events and proposals relating to the development of Temburong ecotown in this analysis framework. These will be discussed in detail in the following subsections:

- Land Transport Master Plan (LTMP) and Transport White Paper
- The opening of Temburong Bridge
- The development of Temburong district following the master plan proposed in ERIA and Nikken Sekkei Civil Engineering Ltd (2018)

3.3.1. LTMP and Transport White Paper

The Ministry of Communications Brunei Darussalam (2017) defined the high level of land-transport mission as achieving an integrated, efficient, safe, clean, and rapid land transport system that offers a choice for all and supports the sustainable economic development of Brunei Darussalam. The basic premise behind the mission is the need to support national economic, social, and cultural development in line with Wawasan 2035, but to achieve this across a range of transport modes and mitigate negative impacts on society and the natural and built environments.

Amongst the national and local programmes defined in the LTMP, we identified three interventions currently being prepared that should soon affect mobility and emission in Temburong district: green vehicle regulations and incentives; improvement to cross-border crossings and customs, immigration, quarantine, and security (CIQS) facilities; and Pan-Borneo highway and public transport enhancements (Table 3.6).

Table 3.6: National and Local Programmes in the Land Transport Master Plan that Might Affect the Mobility and Emissions in Temburong District

Intervention: National and Local Programmes	Preparation Period	Targeted Completion Year
Green vehicle regulations and incentives	2014–2025	2025
Improvements to cross-border crossings and customs, immigration, quarantine, and security (CIQS) Facilities	2016–2022	2022
Pan-Borneo highway enhancements	2018–2024	2024

Source: Extracted from Centre for Strategic and Policy Studies (2014).

Table 3.7: Green Vehicle and Border-Crossing Improvement Interventions

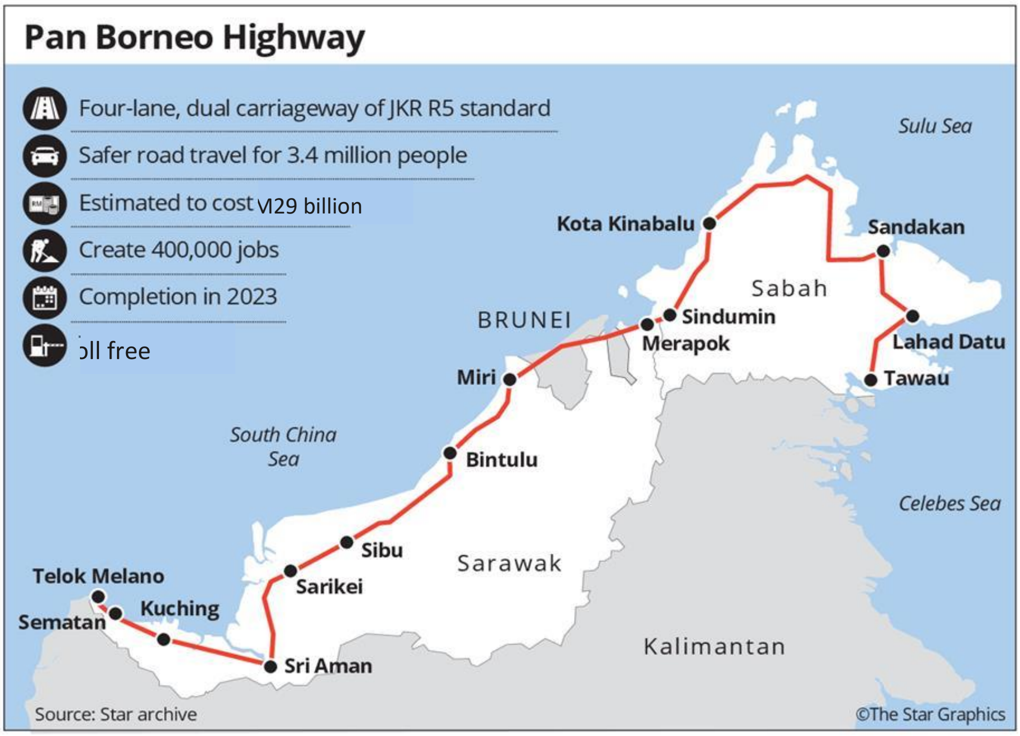
Intervention	Objective	Target Year		Key Actions and Milestones
		2025	2035	
Green vehicle regulations and incentives	Objective 2.2 – Promote energy efficiency and the progressive decarbonisation of the vehicle fleet and fuel cycle	48,000 kg of CO_2 for morning peak hours (down by 31% from reference case)	66,000 kg of CO_2 for morning peak hours (down by 40% from reference case)	● Strengthening of vehicle and fuel emission and consumption standards to Euro V and beyond (to 2025) ● Working with industry on pilot and field trials of zero-emission vehicles, as well as charging infrastructure (to 2025) ● Adoption and mainstreaming of decarbonised vehicle technology including full electric, fuel cells, and hydrogen (to 2035)
		>1% of vehicle fleet electric or hybrid	10% of vehicle fleet fully electric	
Improvements to border crossings and customs, immigration, quarantine and security (CIQS) facilities	Provide efficient access and operation for international gateways for passengers and freight, including ports, jetties, airports, and land border crossings	Journey time targets to airport, border crossings and Muara Port to be set	Journey time targets to airport, border crossings and Muara Port to be set	Linkage of Brunei Coastal Highway to wider improvements to Pan-Borneo Highway in Sarawak and streamlining of border crossing and CIQS procedures (to 2025)

Source: Extracted from Centre for Strategic and Policy Studies (2014).

The third intervention, i.e. Pan-Borneo highway and public transport enhancements, occupies theme no. 6 of the LTMP entitled 'Effective Regional and International Connections Lies in fact in the Framework of Brunei Darussalam, Indonesia, Malaysia, and the Philippines, East ASEAN Growth Area (BIMP-EAGA). This cooperative framework comprises sets of agreements between the four countries launched in 1994. This framework aimed at accelerating economic development in the four countries' focus areas that, although geographically distant from their national capitals, are strategically near each other in one of the world's most resource-rich regions.

Brunei Darussalam shares the Pan-Borneo highway[7] (Figure 3.25) connections and relations with Malaysia and Indonesia. Brunei also seeks regional economic, social, and environmental cooperation through BIMP-EAGA and the wider ASEAN community. Transport connections play an important role in supporting such cooperation and need to be made as efficient, attractive, and effective to reduce the economic and social costs of travel.

Figure 3.25: Pan-Borneo Highway



Source: *The Star* (2018).

Apart from the road network, shipping also plays a vital role in the BIMP-EAGA framework. In this aspect, it might be important to pay attention to the development of Muara Port.

---

[7] The Pan-Borneo Highway is a road network on Borneo Island connecting two Malaysian states, Sabah and Sarawak, with Brunei and Kalimantan region in Indonesia. The highway is numbered AH150 in the Asian Highway Network and as Federal Route 1 in Sarawak. In Sabah, the route numbers are 1, 13, and 22. The length of the entire highway is expected to be about 2,083 kilometres (km) (1,294 mi) for the Malaysian section, 168 km (104 mi) for the Bruneian section, and 3,073 km (1,909 mi) for the Indonesian section. The Indonesian sections of the Pan-Borneo Highway is known as the Trans-Kalimantan Highway. The western route connects Pontianak city to Tebedu.

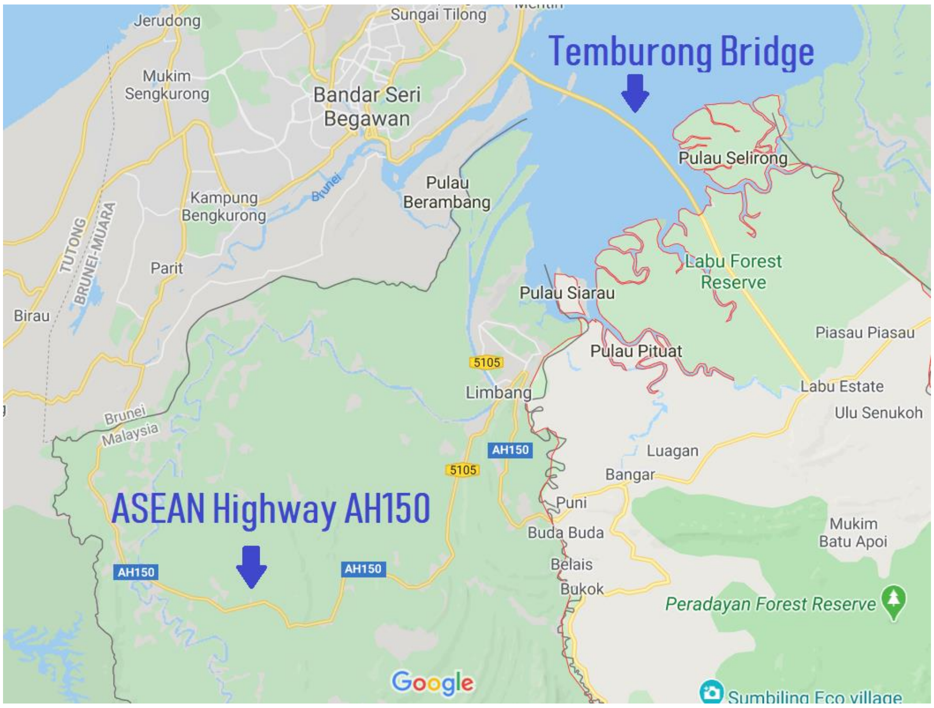
Rahman (2019) categorised Muara Port as a small-scale seaport but the Ministry of Foreign Affairs of the People's Republic of China (2020) considered it as a key focus in developing Brunei's role as a hub within the BIMP-EAGA subregion.

3.1.2. The Opening of Temburong Bridge

Temburong Bridge is a dual-carriageway bridge in Brunei and is the longest bridge in Southeast Asia. Spanning 30 kms, it connects Mengkubau and Sungai Besar in the Brunei–Muara district with the Labu Estate in Temburong district. According to Abu Bakar (2020), the bridge shall reduce travel time between the Brunei capital, Bandar Seri Begawan (BSB), and Temburong district from the current 2 hours of travelling via the Asian or ASEAN Highway 150 passing by the Malaysian Limbang district, or between 1 to 2 hours on a ferry between Brunei Muara and Temburong to less than 30 minutes using the new bridge.

Abu Bakar (2020) reported that Temburong Bridge was opened on 17 March 2020 for public use. The bridge is currently open daily from 6 a.m. to 10 p.m. with some access criteria for motorists using the bridge. Only Brunei-registered vehicles in classes I, III, IV, and VI can use the bridge. Brunei-registered commercial vehicles (class V) are required to apply for permission from the Bridge Maintenance Office. In the meantime, foreign-registered commercial vehicles are advised to continue using the designated ASEAN Highway 150 route, which requires crossing the Brunei Darussalam–Malaysia border twice, i.e. in Tedungan and in Puni, passing through Limbang in Sarawak Malaysia that separates Brunei Darussalam in two parts.

Figure 3.26: Current Main Road Access To and From Temburong District



Source: Google Maps (2020) with author's modification.

3.1.3. ERIA and Nikken Sekkei Civil Engineering Ltd (2018a) Temburong District Following the Master Plan (LTMP)

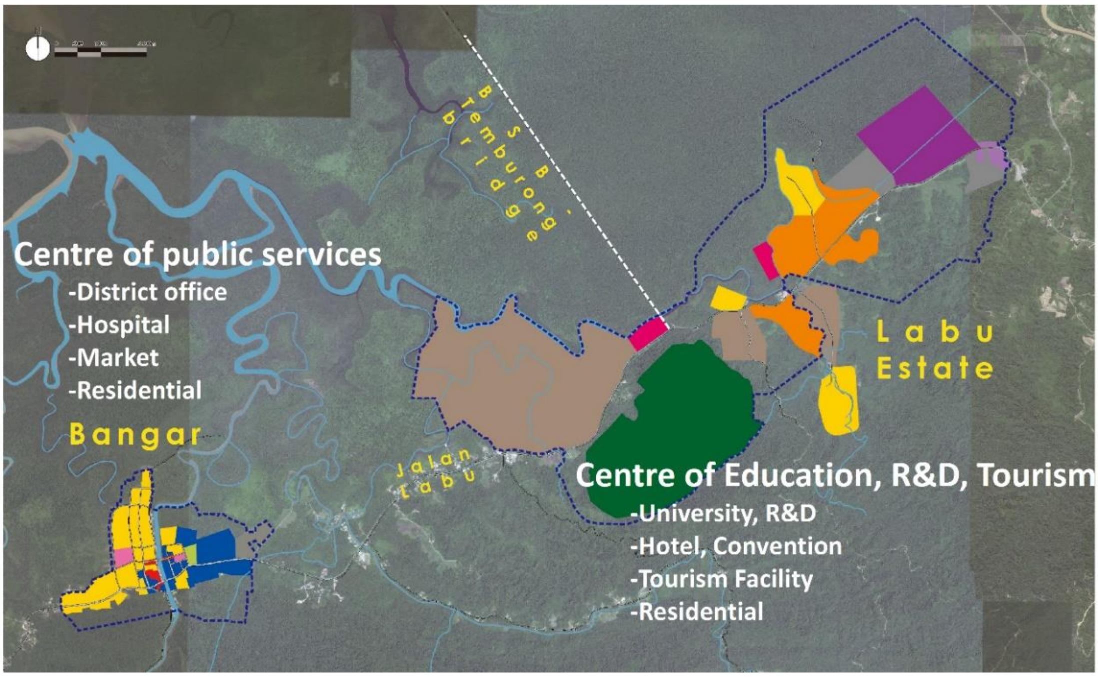
The Ministry of Primary Resources and Tourism (2017) projected that tourism visits to Brunei will increase from 281,213 visitors in 2015 to 451,000 visitors in 2020, a 15.63% annual increase. Temburong district was identified as one of the primary tourism products, together with BSB and Kampong Ayer. For Temburong district itself, the target was to increase the number of visitors from 10,646 in 2015 to 24,000 in 2020 through the development of the Batang Duri River Centre, River Resort; privatisation of the Temburong Rest House, Cultural, and Heritage Gallery; and the organisation of events such as the Temburong Marathon and the building of leisure and theme parks.

ERIA (2018a) proposed to develop Temburong district as a next-generation eco city, as part of the rich ecosystem of Borneo island aiming at zero–carbon emissions. The study proposed the following policies to balance the circulation of energy supply and demand: (i) renewable energy, (ii) a sustainable mobility system, (iii) sustainable architecture and agroforestry, and (iv) a small economy.

A sustainable mobility system is needed to minimise the energy consumption caused by movement. For example, hydrogen-powered buses (CO_2 zero) could bring tourists from BSB to Temburong district and tourists could travel around in Temburong in hydrogen-powered autonomous cars.

Proposing a master plan for the district until 2030 and considering the development plan of the sea bridge connecting BSB and Temburong, the study offered two development hubs in Temburong: Bangar and Labu Estate. As shown in Figure 3.27, Bangar will be the centre of public services and shall house the district office, hospital, market, and residential communities. Labu Estate, on the other hand, will be the centre of education, research and development (R&D), and tourism. It shall house a university, hotels, convention centres, and tourism facilities, including the Ulu Temburong National Park and Perdayan Forest Recreation Park.

Figure 3.27: Suitable Location for Development Hubs in Temburong

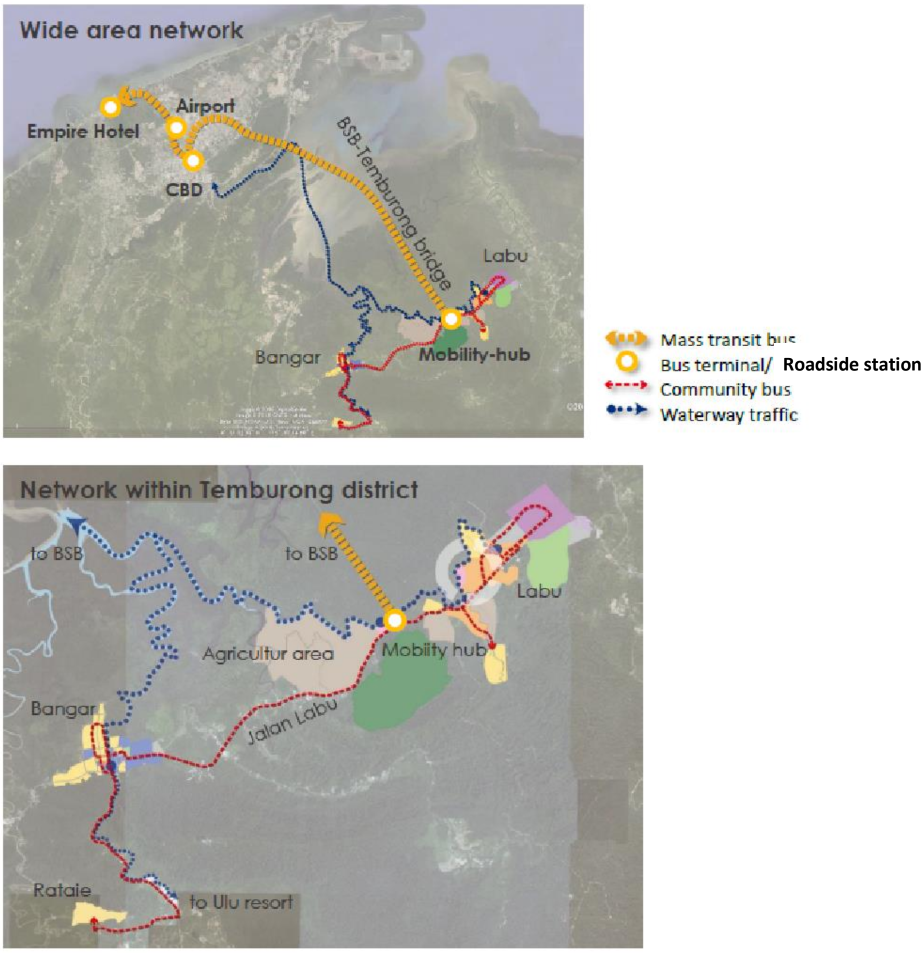


Source: ERIA (2018).

To develop sustainable mobility in Temburong, ERIA (2018) proposed the basic concept of a carbon-neutral society for eco-friendly Temburong district through the following:

- Suppression of traffic volume:
  - Control entry of vehicles from Temburong Bridge
  - Promote carpooling system
  - Introduce public transport
  - Encourage a new logistics system, such as drones, which does not depend on vehicles
- Prioritisation of transport devices with small environmental loads:
  - Develop traffic regulation that gives priority to EVs or FCVs
  - Introduce a transportation device that does not depend on automobiles, such as electric motorcycles
- Introduction of various transport devices to activate ecotourism:
  - Introduce various transportation devices such as autonomous vehicles, boats, buses, taxis, electric motorcycles, and bicycles.

Figure 3.28: Mobility Network of Temburong District

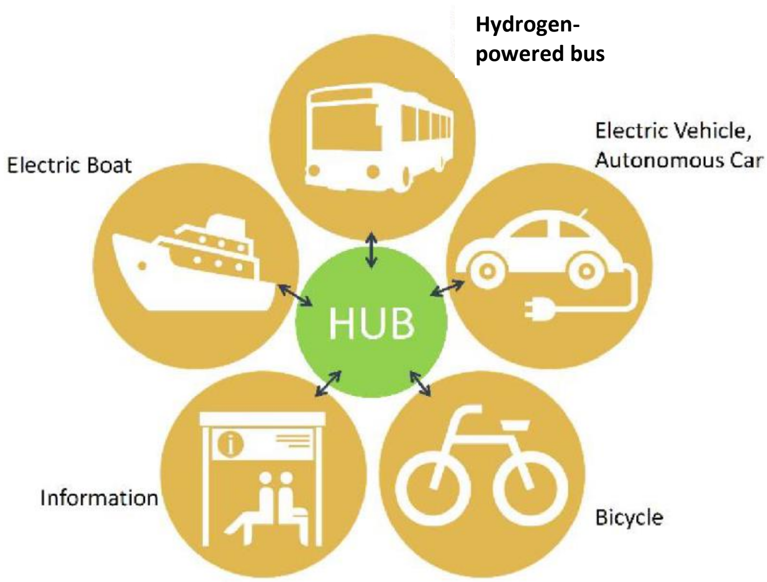


Source: ERIA (2018).

A mobility hub zone was proposed as a place where hydrogen-powered buses, electric cars, autonomous cars, electric boats, and bicycles are connected. Tourists arriving in Temburong from BSB via hydrogen-powered buses can transfer to other means of transport, such as electric cars, autonomous cars, electric boats, and bicycles, to go to other tourist spots.

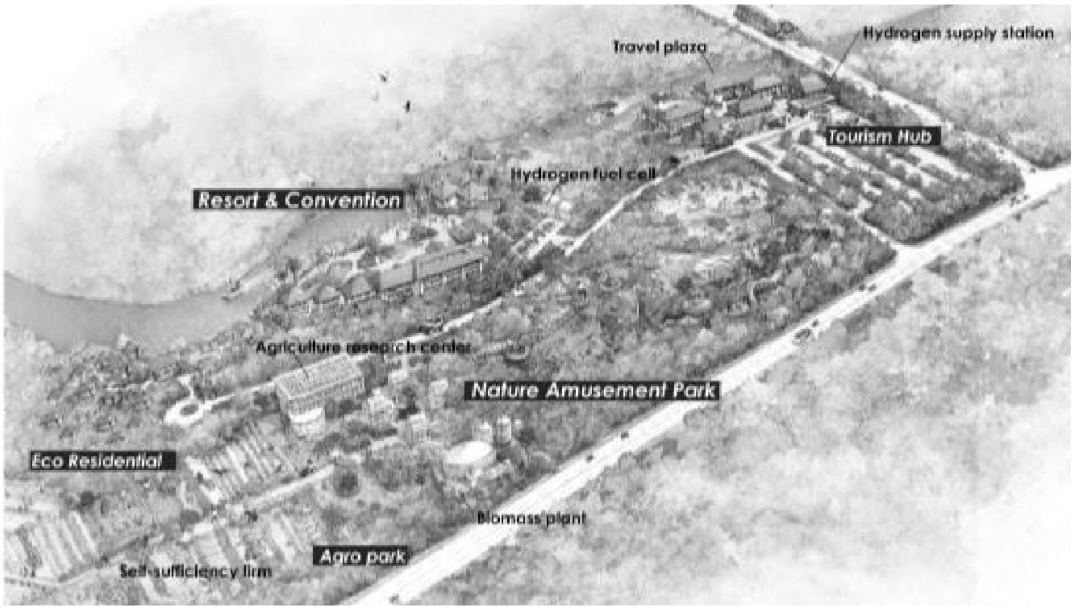
With the travel plaza here, tourists can enjoy many services such as accessing tourism information, booking tours and accommodation, and using the hydrogen supply station.

Figure 3.29: Mobility Hub Design



Source: ERIA (2018).

Figure 3.30: Mobility Hub Zone



Source: ERIA (2018).

3.2. Development of a low-carbon traffic system scenario

3.2.1. Methodology for Calculating Emissions from the Transport Sector

A basic methodology for calculating emissions from the transport sector is known as the ASIF methodology (Schipper et. al., 2000). The acronym ASIF stands for Activity-Structure-Intensity-Fuel data matrix.

Equation (3)…

$$G = \sum_{mode} \sum_{fuel} A_{mode,fuel} \cdot S^{-1}_{mode,fuel} \cdot I_{mode,fuel} \cdot F_{fuel}$$

where:

G = total emissions of GHGs in the regions, for example, given in tonnes of CO_2
A = transport activity in passenger- and/or tonne-kilometres
S = structure variable representing the load factors for the various modes and fuel types, i.e. occupancy of passenger vehicles such as passengers per vehicle, and an equivalent measure for freight, such as tonnes per vehicle.
I = measures of energy intensity in energy per vehicle kilometre for each mode and fuel type, which can be represented by vehicles' fuel economy given, for example, in litre/vehicle-kilometre.
F = simple carbon per energy constant for each fuel type.

3.2.2. Current Situation and the Potential Changes in the Traffic of Temburong District

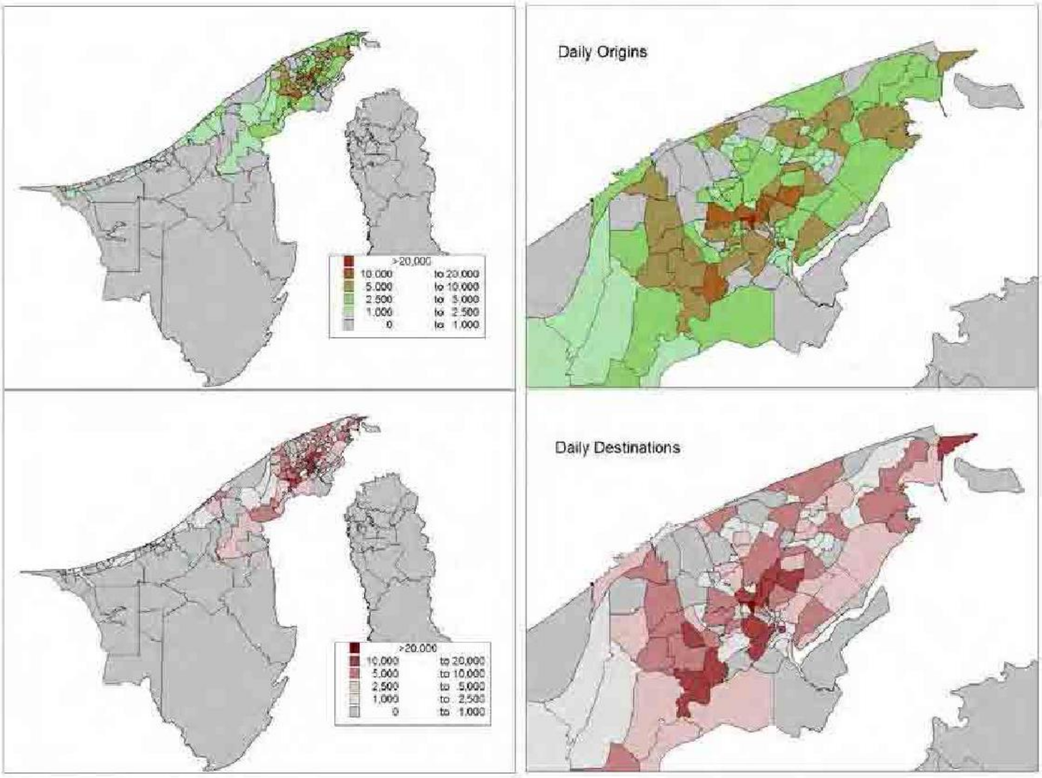
The Centre for Strategic and Policy Studies (2014) recorded that trip across Brunei is around 800,000 person-trips per day (from 7 a.m. to 7 p.m.), accounting for vehicle occupancy, the vast majority of which are by car. Over 300,000 vehicles were recorded in total at the Roadside Interviews (RSI) in 2014.

According to the survey conducted by the Centre, the daily total number of trips to and from Temburong district in 2012 was amongst the lowest in the whole Brunei Darussalam (Figure 3.31).

With the Temburong district as a primary tourist destination in Brunei and with the opening of the Temburong Bridge on 17 March 2020, the number of trips would increase significantly, not only those coming from or going to Temburong but also those passing through.

The two events will induce attraction to the district and, therefore, considerably increase the volume of inbound and outbound traffic, internal traffic, and passing-through traffic. Without any environmentally emphasised intervention and policy measures, the increasing traffic would be harmful to the district.

Figure 3.31: Daily Trip Origins and Destinations (All Modes – Persons) in 2012



Source: Centre for Strategic and Policy Studies (2014).

3.2.3. Proposed Framework for Developing a Low-Carbon Traffic System

Using the methodology to calculate GHG emissions as defined in Section 3.3.2.1, we estimated the contribution of the different interventions or policy measures (as described in Section 3.3.1).

Table 3.8 summarises the interventions or policy measures. We qualitatively estimated the effect of each intervention or measured implementation to each element (independent variable) of the GHG emission equation, i.e. activity, structure, energy intensity, and fuel carbon content. We then estimated the total impact of the measure on the total GHG emissions.

Table 3.8: Estimated Effect of Each Intervention to the Total Emissions of Greenhouse Gases in Temburong

Intervention	Activity (A)			Structure (S)		Energy Intensity (I)	Fuel Carbon Content (F)	Total Emissions of Greenhouse Gases (G)
	Inbound and outbound traffic	Internal traffic	Through traffic	Passenger occupancy rate	Freight load factor			
Brunei Darussalam Land Transport Master Plan								
Green vehicle regulation incentive	0	0	0	0	0	- -	- -	- -
Improvements to border crossings and CIQS facilities	+	+	+	0	0	0	0	+
Pan-Borneo Highway enhancements	+ +	+	+ +	0	0	0	0	+
Opening of Temburong Bridge	+ + +	+ + +	+ + +	0	0	0	0	+ + +
ERIA (2018) Master Plan for Temburong								
Control entry of vehicles from Temburong Bridge	- -	0	-	0	0	0	0	-
Promote carpooling system	-	-	0	+ +	0	0	0	- -
Introduce public transportation	-	+	0	+ +	0	0	0	- -
Encourage a new logistics system, such as drones, which does not depend on vehicles	0	-	0	0	0	0	0	-
Develop traffic regulations that prioritise electric	-	0	0	0	0	- -	- -	- -

vehicles or fuel cell vehicles								
Introduce transport devices that do not depend on automobiles, such as electric motorcycles	+	+	0	0	0	-	-	-
Introduce various transport devices such as autonomous vehicles, boats, buses, taxis, electric motorcycles, and bicycles.	+	+	0	+	0	-	-	-

Notes: 0 = neutral, -= slight reduction, - -= significant reduction, - - - = strong reduction, + = slight increase, + + = significant increase, + + + = strong increase.
CIQS = customs, immigration, quarantine, and security.
Source: Author's elaboration.

4. Conclusions and Way Forward

Introducing low-carbon types of vehicle propulsion, namely, electric- and hydrogen-powered FC cars, would benefit Brunei in reducing total GHG emissions. However, the effects of BEV penetration on total emissions depend on the emission intensity of the power generation sector, whilst those of FC hydrogen vehicles rely on the emission intensity of hydrogen production.

Temburong district's designation as the main tourism destination in Brunei and the Temburong Bridge's opening will increase the district's attractiveness and increase traffic volume. These might also potentially increase total GHG emissions. The accompanying environment- and climate-related measures and interventions should realise the concept of ecotown, which should at least be carbon neutral.

The LTMP of Brunei and the ERIA master plan proposal for Temburong district provide some measures that should be implemented to ensure the realisation of the ecotown concept. Each measure or intervention contributes differently and in different intensities to the reduction of GHG emissions. This report quantitatively assessed these contributions.

Finally, the government might need to elaborate emission- and air pollution–capping policies for road vehicles using the Pan-Borneo Highway, especially in freight transport trips carried by commercial vehicles, such as heavy- and light-duty trucks and vans. The policies' primary objective is to decouple GHG emissions and air pollution growth from the freight movements along the Pan-Borneo Highway, especially those to and from Brunei and Temburong district and those just passing through. Herewith, the climate and environmental impacts of growth in trade in the concerned regions can be minimised.

As a continuation of this study, we recommended the following two steps to get more detailed impact assessment results of the different policy measure options for Temburong district's mobility.

First, develop a network-based traffic model for Temburong district that should serve as a tool to simulate the impacts of all transport-related policies in the framework of the district's development. The model should cover defined future period forecasted demand broken down into the different origins and destinations inside the district, between the different origins and destinations in the district, and the main external origins and destinations and the origins and destinations related to passing-through traffic. Herewith, the model should have a detailed representation of the Temburong road network's detailed disaggregation of origins and destinations outside the district, including origins and destinations in the relevant foreign countries. The demand should be detailed into the different vehicle types that should calculate energy use, air pollution and emissions, and assigned to the road network to enable micro-level analysis of traffic impacts, including congestion.

Second, use the above network-based traffic model as the primary tool to quantitatively assess the climate and environmental impacts of the different transport-related policy measures and interventions in Temburong district, Brunei Darussalam, or in a wider geographical scope, such as in the Pan-Borneo Highway or BIMP-EAGA framework.