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Carbon Footprint Assessment at Rest and Service Area of Malaysia Highway

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Malaysia has committed to reduce its greenhouse gas (GHG) emissions by up to 45 % by the 2030. With increasing urbanisation and living standards of people in Malaysia, there is certainty that there will be a substantial increase in human activities hence mobility via networks of the highway. Rest and Service Area (RSA) is one important facility of the highway network that operates 24 hours and utilises significant amount of energy for its lighting, cooling, and the restaurants activities. A substantial amount of carbon is emitted from the RSA due to electricity usage, water consumption, solid waste and wastewater, as well as fuel consumption from staff commuting and transportation of goods. The objective of this study is to identify the sources and estimate the operational carbon footprint at RSA Highway Malaysia. The collected data questionnaire was analysed using Microsoft Excel. As expected, the amount of CO_2 emissions from electric consumption for each selected RSA about 90 to 94 % of carbon release compare to other sources. As a conclusion, the investments including a more efficient HVAC system and more efficient lighting, could make the building more energy efficient and may induce greater use.

1. Introduction

Many countries including Malaysia are playing an active role in reducing CO_2 emissions through national mitigation and intergovernmental mechanisms which aimed reducing atmospheric concentrations of Greenhouse gasses (GHGs). Latest, Malaysia has agreement to reduce its GHG emissions intensity of GDP by 45 % by 2030 relative to the emissions intensity of GDP in 2005 (The Government of Malaysia, 2015). Malaysia has rapidly transformed from an agricultural to an industrialised economy in the last four decades, with an alarming growth of GHG emissions that are caused by the escalating number of automobiles, factories and power plants (Zaid et al., 2014). Previous research projected that without any mitigation measures, Malaysia's CO_2 emission in 2020 will amount to 285.73 t CO_2-eq; a 68.86 % increase compared to 2000 (Safaai et al., 2010). The aim of this study is to address the challenge of setting realistic operational carbon reduction targets for the operation of RSA at Malaysia Highway. Normally, RSA operates 24 h/d and utilises energy for its lighting, cooling, and also the restaurants activities (Zakaria et al., 2013). Several scenario analysis were carried out in order to identify the sources and estimate the operational carbon footprint at RSA of Highway Malaysia.

2. Literature review

Proper management and control need to be implemented to reduce emissions of greenhouse gases. Presently, Malaysia has no energy efficiency legislation in its growing building sector. Wang et al. (2018) stated that the operation and management of service area is the key to offering potential value which may increase carbon sink and decrease carbon emission. As developing countries like Malaysia that growing

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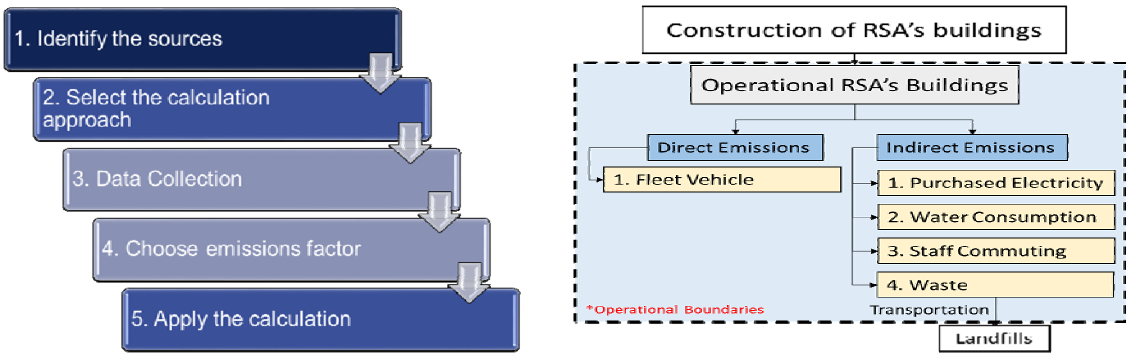
demand for construction, it is important to invest in more energy efficient buildings and prevent the 'carbon lock-in' effect (Zaid et al., 2014). From report International Energy Agency, the building sector's primary contribution of GHG emissions is the result of fossil fuels being used to generate electricity or used directly for building operations, in the form of fuel combustions, produces 40 % of global wastes, and consumes approximately 16 % of water sources (IEA, 2017). Residential buildings represent 65 % of the global total sectoral emissions, and 35 % for commercial building (Baumert et al., 2005).

In the United States, it was reported that about 35 to 40 % of total energy was consumed in buildings in the developed countries with 50 to 65 % of electricity consumption (U.S. Energy Information Administration, 2017). According to Ramachandra et al. (2015), carbon footprint is the total amount of greenhouse gases impacting the environment that produced both directly and indirectly due to various human activities by an individual, event, organisation, and product, expressed in metric tonnes carbon dioxide equivalent (t CO_2-eq) (Ramachandra et al., 2014). The build-up of CO_2 is causing the Earth's atmosphere to warm, resulting in changes to the climate we are already starting to see today (Environmental Protection Agency, 2017).

3. Methodology

The research method is based on guideline from Greenhouse Gas Protocol (GHG Protocol) which developed by World Resources Institute (WRI) and World Business Council on Sustainable Development (WBCSD). The step in estimating the GHG emissions as illustrated in Figure 1a. The carbon footprint was measures GHG emissions from all the activities across the organisation, including energy used in buildings, industrial processes and company vehicles. However, the embodied energy is excluded from this assessment because the initial energy required to produce the RSA building materials plus transport energy required to transport the materials to the construction site are not include in research boundaries as in Figure 1b. The selected RSAs were at RSA 1 (Ayer Keroh Northbound), RSA 2 (Overhead Bridge Restaurant Ayer Keroh Northbound/Southbound) and RSA 3 (Pagoh Northbound).



(a) (b)

Figure 1: Methodology of study which are (a) steps in calculating the carbon emissions and (b) operational boundaries of the study

In order to calculate carbon footprint at selected RSA, the operational boundaries were defined to determine which compartment units and which activities that result in carbon emissions will be included in the RSA's carbon emissions inventory which listed in Table 1. The boundaries of the study will be divided into two categories (direct and indirect emissions) according to the GHG Protocol models as in Figure 1b. The estimate method was selected as calculation approach which the most common approach for calculating GHG emissions. The data was collected from focus group interview among expert group of government agencies and highway concessionaires and the questionnaire survey among workers at RSA's stall. The emission factor was based on IPCC, Defra and previous study. The calculation of carbon emission is based on that Eqs (1) – (5):

$$\text{Water Consumption} = \text{Water Consumed } (m^3) \times \text{Emissions Factor} \quad (1)$$

$$\text{Electric Consumption} = (\text{Electric Bills} \times \text{Emission Factor}) / (\text{Electric Tariff}) \quad (2)$$

$$\text{Fuel Consumptions: Distance Based Method} = \text{Litres (L)} \times \text{Emissions Factor} \quad (3)$$

$$\text{Fuel Based Method} = \text{Distance (km)} \times \text{Emissions Factor} \quad (4)$$

$$\text{Solid Waste} = [\text{Weight (kg)} \times \text{Emissions Factor}] / 1{,}000 \quad (5)$$

Table 1: The main carbon emission source at RSA

No.	Categories	Scope	Data Sources
1.	Electric Consumption	2	• Metered electricity consumption • Utility bill/monthly energy consumption bill (Total kilowatt hours (kWh) used)
2.	Water Consumption	3	• Water Bill • Total water used in cubic meter (m^3)
3.	Staff Commuting	3	• Distance/length travelled from home to work place • Type of fuel used (diesel/petrol) • Type of vehicle
4.	Fleet Vehicle	1	• Distance/length travelled from work place to RSA • Work maintenance schedule
5.	Solid Waste	3	• Distance/length travelled from RSA to landfill • Amount of waste produced in one day (kg) • Type of fuel used (diesel/petrol)

4. Result and discussion

4.1 To identify the sources of greenhouse gases emissions

The identification of direct emissions and indirect emission shown as below. The floor area at RSA 2 is the biggest with 3,700 m^2 followed by RSA 1 and RSA 3 with 2,880 m^2 and 2,820 m^2.

4.1.1 Electrical consumption

The consumption of electric in Figure 2a was calculated based on the RSA's area. From that figure, the electric usage in 2016 at RSA 2 is highest with 714.23 kWh/m^2. This is because this RSA use system HVAC which means heating, ventilation, and air conditioning. This RSA also located at overhead bridge so it needs more energy in lighting to make this area more attracted and beautiful when the highway users cross along the bridge. The number of street light at RSA 2 also is higher compare to RSA 1 and RSA 3. Overall, the lowest usage of electric was recorded on 2017 at RSA 3 with 340.77 kWh/m^2 while for RSA 1 and RSA 2, the lowest usage of electric were 355.92 kWh/m^2 and 679.74 kWh/m^2 in 2015. For RSA 3 and RSA 1, the highest electrical consumptions were recorded in 2015 and 2016 with 379.77 kWh/m^2 and 370.17 kWh/m^2.

4.1.2 Water consumption

The consumption of water in Figure 2b was calculated based on the RSA's area. From that figure, Restaurant OBR Ayer Keroh RSA was the highest water consumption compare to the other two selected RSA. Starting from 2015 until 2016 the water usage at RSA 2 climbed dramatically by 23.79 m^3/m^2 to just over 42.50 m^3/m^2 only two years later. In 2015, the water consumption at RSA 2 had dropped down but the electric usage is still high and almost same with other year. This is because the maintenance and renovation were run at southbound area RSA 2 only. The activities of maintenance and renovation use many machines with electric power beside the usage of lighting at this area. Overall, the lowest usage was recorded in 2017 with 23.25 m^3/m^2 at RSA 1 and the highest water consumption was at RSA 2 with 42.5 m^3/m^2 in 2017. For RSA 3, it is a bit constant water consuming from 2015 until 2017 between 18.86 to 22.22 m^3/m^2. This means that RSA 3 has a good quality in management of water. It clearly be seen that the water usage decreased slightly at RSA 1 from 2015 to 2017. This because of the 3 main meter at Police Post, Toilet and Prayer Room have been terminated as stated in monthly maintenance report.

4.1.3 Fleet vehicle

There are six fleet vehicles owned by PLUS S2 section which are van, car, motorcycle, Hilux, crane and slide deck that use for maintenance of the facilities at RSA. Maintenance activities mainly include the inspections, equipment and infrastructure maintenance, emergency responses, management assessments, safety assessments, and decision-making as well as engineering information management. The maintenance for RSA will do every day such as for prayer facilities, building maintenance like floor, wall, window panels / louvres, notice and signboard, litter bin and also toilet amenities. For grass maintenance and drainage system they will do maintenance every 2 weeks for slope, flat area and slope fence. Figure 3a show the overall maintenance distance they had travelled in 2017.

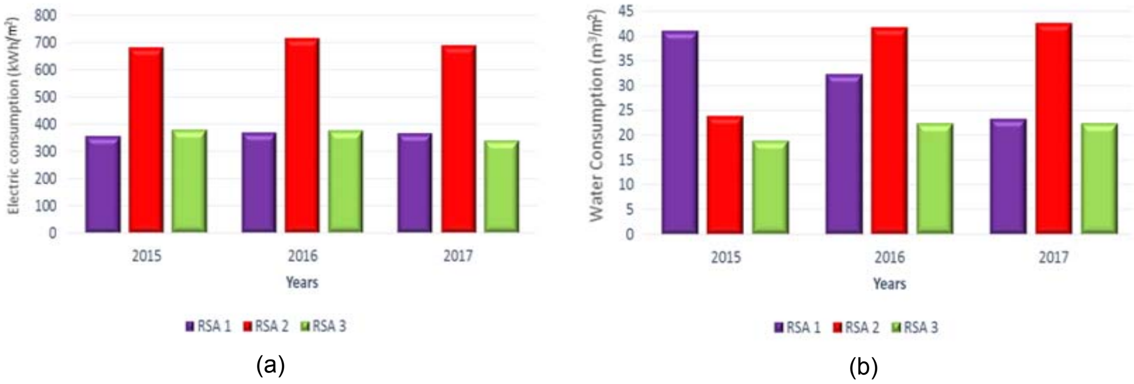


Figure 2: Utility consumption of RSAs from 2015 until 2017 where (a) electrical usage (kWh/m^2) and (b) water usage (m^3/m^2)

4.1.4 Staff commuting

For this section, the data were conducted by using questionnaire survey for every stall worker at selected RSA. From Figure 3b, the distance that have been travelled by staff was tabulated in graph. The stall worker at RSA 3 choose motorcycles as transportation is the highest compare to other two RSA. They have been travelled approximately about 146,880 km/y. At RSA 2, the stall's worker use car for commuting and transportation of goods is the highest compare to other two RSA which about 110,160 km/y. The total approximate amount of fuel used at the RSA 1 is 142,560 L for petrol and 6,059.94 L for diesel. For RSA 2 and RSA 3, the amount of petrol fuel used are 219,600 and 198,720 L and for diesel fuel are 6,343.76 and 4,985.97 L.

4.1.5 Waste transportation

From the data work schedule, the distance from each RSA have been plotted in Figure 3c. The collected waste from RSA 1 and RSA 2 were sent to the Sungai Udang Sanitary Landfill which the distance about 37 km from the RSA but unfortunately this landfill is almost full and there is only limited space now. The quantity of waste disposed and location of illegal dumpsites were not part of the study because of lack of data and it's hard to record the data for each RSA. For RSA 3, the waste was transport to the Seelong Environmental Centre which located quite far about 171 km from RSA 3.

4.1.6 Waste quantity

From the data questionnaire survey, RSA 1 is the highest with 8,100 kg followed by RSA 3 and RSA 2 with 7,200 kg and 6,660 kg/y as can see in Figure 3d. In one day, average 20 kg of waste will be produced at each RSA. The type of wastes are from plastic, food waste, papers, bottle and tin aluminium. From the observation, there is no recycling available at three selected RSA. This is maybe because the staff did not seem to have an interest in such a program due to safety issues (encountering syringe needles, or meth-lab residues) or will enticing wildlife to look for food in the recycling receptacles. Furthermore, the local authorities that responsible for waste management do not clearly understand the linkage between waste management and climate change. The data composition of waste was according to the Jabatan Pengurusan Sisa Pepejal Negara Malaysia for commercial building.

4.2 To estimate the carbon footprint in terms of CO_2-eq

In most circumstances, GHG emissions cannot be directly measured. GHG emissions must be calculated using measured the activity data for parameters such as quantities of fuel combusted, type of vehicle, quantity of waste or vehicle miles driven. Unfortunately, this kind of data does not record for the previous year then an assumption has been made in order to estimate the carbon footprint at RSA. The data for transportation and quantity of waste in 2015 and 2016 are assume same like 2017 because lack of data recorded. Since the data for Scope 1 in 2017 is assume same with 2015 and 2016, RSA 2 was recorded as highest carbon emissions with 20.12 t CO_2-eq/y followed by RSA 1 and RSA 3 with 3.98 and 4.83 t CO_2-eq/y. In terms of Scope 2, one category has been included which is purchased electricity from main sub-meter. The total of Scope 2 carbon emissions at RSA 1 are increasing from 2015 to 2016 which from 767.22 to 794.99 t CO_2-eq/y. This because of less efficiency of purchased electricity consumption in 2016.

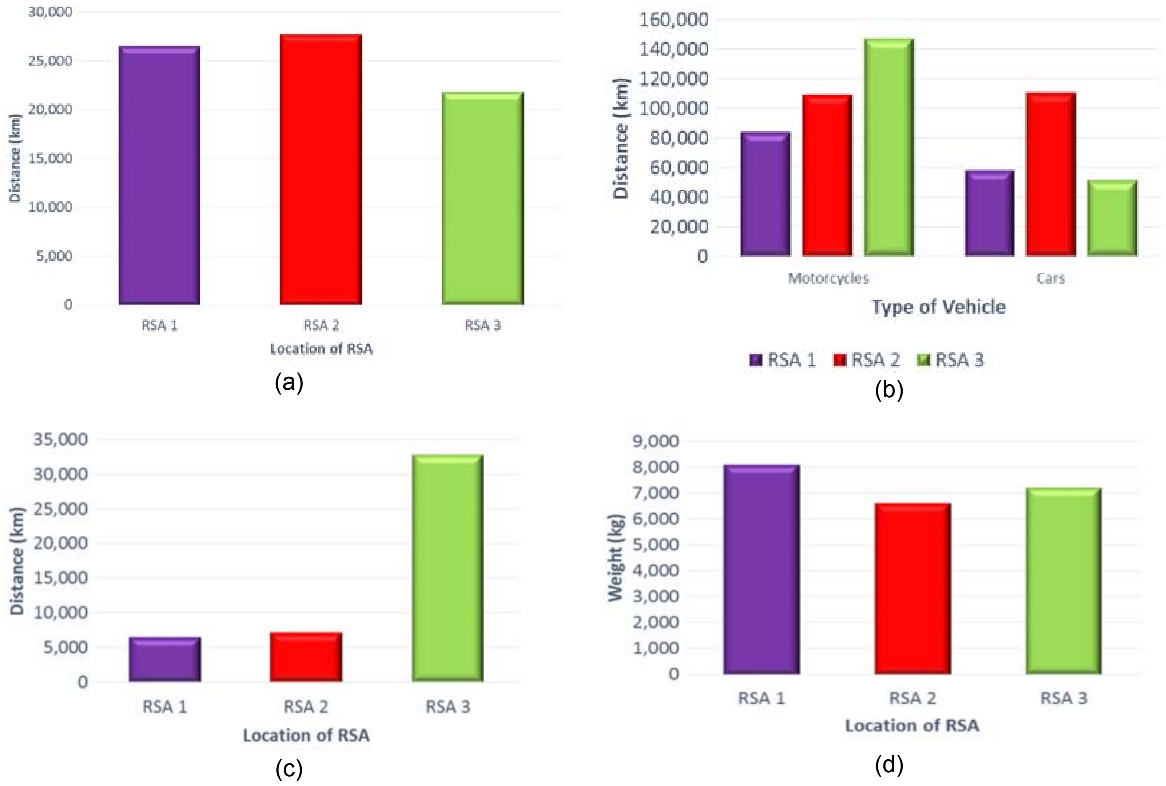


Figure 3: Data for carbon emissions estimation for each RSA (a) overall maintenance distance travelled by fleet vehicles; (b) distance travelled by staffs for different types of transportation; (c) total distance for waste transportation to waste disposal site; and (d) quantity of wastes produced

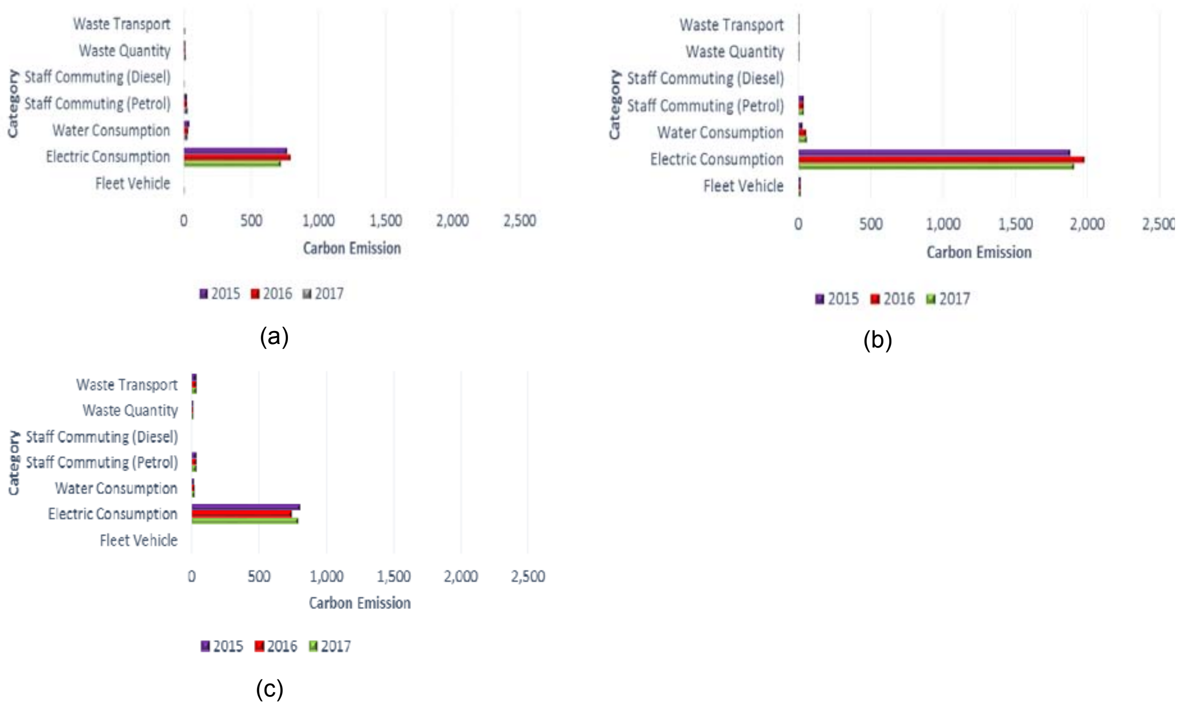


Figure 4: Breakdown of carbon emissions from 2015 - 2017 for (a) RSA 1; (b) RSA 2; (c) RSA 3

The purchased electricity has been managed well in 2017 which 719.26 t CO_2-eq/y compared to 2016. For the record, RSA 2 was the highest total of Scope 2 carbon emission release compared to other two RSA with the average 1922.11 t CO_2-eq/y. For RSA 3, the total of Scope 2 carbon emission was decreased from 2015 to 2016 which are from 801.57 t CO_2-eq/y to 742.76 t CO_2-eq/y but then in 2017 the result slightly increased to 789.24 t CO_2-eq/yr. Overall from Figure 4a, 4b and 4c, the electrical consumption is dominant of carbon emission at three selected RSA compare to other sources. The total of Scope 3 carbon emission at RSA 1 are decreasing from year 2015 to 2017 which from 93.18 to 74.01 t CO_2-eq/y. At RSA 2, the total carbon emission is the highest compare to other two RSA with average 113.36 t CO_2-eq/y. For RSA 3, the total carbon emission increased from 2015 to 2016 with 106.39 to 110.03 t CO_2-eq/y and decrease in 2017 with 109.95 t CO_2-eq/y. Mostly for all selected RSA, the staff commute from their place using petrol as fuel compare to diesel.

5. Conclusions

Generally, the energy consumption is the main source of the carbon emissions at RSA. The amount of CO_2 emissions from electric consumption for each selected RSA about 90 to 94 % of carbon release. Such increased consumption will have significant greenhouse gas externality consequences such as heating and cooling of large structures which requires additional equipment to bridge large vertical distances. As a conclusion, energy conservation methods could be considered to reduce energy consumption in the RSA such as using motion sensors to initiate lighting in the restroom areas or using LED lamp at the street light and high mast in order to make the RSA building more energy efficient and reduce the carbon emissions.

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References

Baumert K.A., Herzog T., Pershing J., 2005, Navigating the Numbers: Greenhouse Gas Data and International Climate Policy, World Resources Institute, Washington, USA.

Environmental Protection Agency (EPA), 2017, Carbon Pollution from Transportation <www.epa.gov/air-pollution-transportation/carbon-pollution-transportation> accessed 30.04.2018.

International Energy Agency (IEA), 2017, CO_2 Emissions from Fuel Combustion 2017-Highlights, International Energy Agency, Vol 1, Bonn, Germany.

Ramachandra T.V., Aithal B.H., Sreejith K., 2015, GHG footprint of major cities in India, Renewable and Sustainable Energy Reviews, 44, 473–495.

Ramachandra T.V., Shwetmala K., Dania T.M., 2014, Carbon Footprint of the Solid Waste Sector in Greater Bangalore, India, In: Muthu S. (Eds) Assessment of Carbon Footprint in Different Industrial Sectors, Vol 1, EcoProduction (Environmental Issues in Logistics and Manufacturing), Springer, Singapore, Singapore.

Safaai N.S.M., Noor Z.Z., Hashim, H., Ujang, Z., Talib, J., 2010, Projection of CO_2 Emissions in Malaysia, Environmental Science & Technology, 30 (4), 482–489.

The Government of Malaysia, 2015, Intended Nationally Determined Contribution of the Government of Malaysia, United Nations Framework Convention on Climate Change (UNFCCC), New York, USA.

U.S. Energy Information Administration, 2017, International Energy Outlook 2017 Overview <www.eia.gov/outlooks/ieo> accessed 27.04.2018.

Wang S., Zhao J., Wang K., Liu Y., 2018, Study on the Low-Carbon Operating Evaluation Model in Expressway Rest Area, Green Intelligent Transportation Systems, GITSS 2016, Lecture Notes in Electrical Engineering, Vol 419, Springer, Singapore, Singapore.

Zaid S.M., Myeda N.E., Mahyuddin N., Sulaiman R., 2014, Lack of Energy Efficiency Legislation in the Malaysian Building Sector Contributes to Malaysia's Growing GHG Emissions, E3S Web of Conferences, 3, 1-9.

Zakaria R., Foo K.S., Ainee F., Majid M.Z.A., Zin R.M., Hainin M.R., Nurfatimah M., 2013, Energy Consumption and Potential Retrofitting of Rest and Service Areas (RSAs) in Malaysia Case Study, Applied Mechanics and Materials, 284–287, 1311–1314.