# EMISSION INVENTORY FOR POWER PLANTS AND PASSENGER CARS IN PENINSULAR MALAYSIA FOR THE YEARS 2008-2014

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## ABSTRACT

*The Department of Environment of Malaysia has identified power plants and motor vehicles as major sources of air pollution. In 2014, both power plants and motor vehicles contributed 23% and 68% of air pollutants to air pollution, respectively. The purpose of this study is to develop an emission inventory – a record of data that lists the amount and location of air pollutant emissions – for power plants and passenger cars in Peninsular Malaysia from 2008 to 2014. The emission inventory focuses on air pollutants and greenhouse gases, $SO_2$, $NO_X$, $PM_{10}$, $PM_{2.5}$, CO, $CO_2$, and $N_2O$. To develop the emission inventory, we used the "simple" method. Activity data for the power plants are fuel consumption, while activity data for the passenger cars are fuel consumption and vehicle kilometre travelled. We assumed default emission factor values due to unavailability of Malaysia-specific values. The results show that in 2014, the power plants of the independent power producers emitted 35.1 metric tons while the national power producer emitted 14.6 metric tons of air pollutants ($SO_2$, $NO_X$, $PM_{10}$, $PM_{2.5}$, CO, and $CO_2$). As for the passenger cars, the mass of air pollutants and greenhouse gases ($NO_X$, CO, $N_2O$, and $CO_2$) emitted, for petrol was 36.2 metric tons while for diesel was 26 metric tons. We projected that by 2020, based on the year 2008, the power plants will emit 56.5 metric tons of $SO_2$, $NO_X$, $PM_{10}$, $PM_{2.5}$, CO, and $CO_2$ at a cumulative growth rate of 15.6%, and the passenger cars will emit 122.9 metric tons of $NO_X$, CO, $CO_2$, and $N_2O$ at a cumulative growth rate of 67.2%.*

**Keywords:** Air pollutants**,** air pollution**,** emission inventory**,** mobile combustion, stationary combustion.

## INTRODUCTION

The Department of Environment of Malaysia estimated that motor vehicles and power plants release large amounts of pollutants to the atmosphere (68% and 23% of the total air pollutants emitted, respectively). These reported values were projected from emission factors and emission inventories retrieved from international emission inventory guidelines. Currently, there are no specific emission factor or emission inventory for Malaysia. In this study, we developed a preliminary emission inventory for power plants and passenger cars for Peninsular Malaysia for the years 2008 to 2014. This effort is the first step in constructing a detailed and accurate emission inventory for Malaysia.

An emission inventory is a data record that tabulates the source and mass of air pollutants emitted from emission sources for certain periods and locations. A detailed national emission inventory is a yearly report that comprises of emission rates of "criteria air pollutants" and greenhouse gases from categories of air pollution sources or "sectors". Criteria air pollutants are sulphur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), carbon monoxide (CO), and particulate matter (PM) while greenhouse gases are carbon dioxide ($CO_2$), nitrous oxide ($N_2O$), and methane ($CH_4$). The sectors include the stationary fuel combustion sector (power plants), the mobile fuel combustion sector (passenger cars), and the industrial processes sector (manufacturing plants), among others. The emission inventory can be developed using the "simple" method where the emission rate is the product of the "activity data" (mass of fuel consumption, vehicle kilometre travelled, etc.) and the emission factor (mass of pollutant emitted per activity data).

The lack of emission factors and emission inventories reduce the utility of estimated emissions for environmental risk assessments and economic planning endeavours. Thus, it is imperative that a detailed and specific emission factor and emission inventory be developed for Malaysia. Towards this end, this paper reports the preliminary emission inventory for the years 2008 to 2014 for power plants and passenger cars for Peninsular Malaysia.

## METHODS

### International emission inventory guidelines

Several emission inventory guidelines detail reliable methods in developing an emission inventory for the stationary fuel combustion and mobile fuel combustion sectors. These guidelines are the Guidelines for Developing Emission Inventory for East Asia 2011, The Global Atmospheric Pollution (GAP) Forum Air Pollutant Emission Inventory Manual 2012, and the European Monitoring and Evaluation Program/European Environment Agency (EMEP/EEA) Emission Inventory Guidebook 2013. These guidelines provide crucial information in developing emission inventory suited for our intended purposes and identified sectors [1-3].

### Data requirements for power plants

Power plants release large quantities of $SO_2$, $NO_2$, CO, PM, and $CO_2$. Power plants burn fossil fuel to produce electricity [4]. There are four types of electricity producers in Malaysia, which are the national power producer (TNB), the independent power producers (IPP), the co-generation producers, and the self-generation producers. Figure 1 shows the distribution of power plants in Peninsular Malaysia. There are six TNB power plants and seventeen IPP power plants. Emission factors for power plants depend on the fuel-type used. There are three types of power plants in Malaysia, the coal-fired, gas-fired, and the gas-coal-fired or gas-oil-fired combination power plants. To date, there are fourteen gas-fired, four coal-fired, and five combination power plants in Peninsular Malaysia [5]. Per the Energy Commission of Malaysia, most power plants use natural gas, followed by coal and oil. Because natural gas and coal are cheap, most of the electricity supply comes from the gas-fired and coal-fired power plants. Power plants rarely use oil as it is expensive [6]. We gathered the emission factors for each fuel-type used, the amount of fuel consumed, and the location of the power plant to develop the emission inventory for Peninsular Malaysia.

Although the emission factors for power plants can be calculated, we used the default emission factors from guidelines instead of the Malaysia-specific emission factor due to unavailability of data. The activity data for power plants (i.e., the amount of natural gas, coal, or diesel consumption) need to be in the unit of Net Calorific Value (NCV) as most of the emission factors available in the literature are using this unit [1]. The activity data are calculated using Eq. (1).

$$Activitydata = Fuelconsumption \times NCV \quad (1)$$

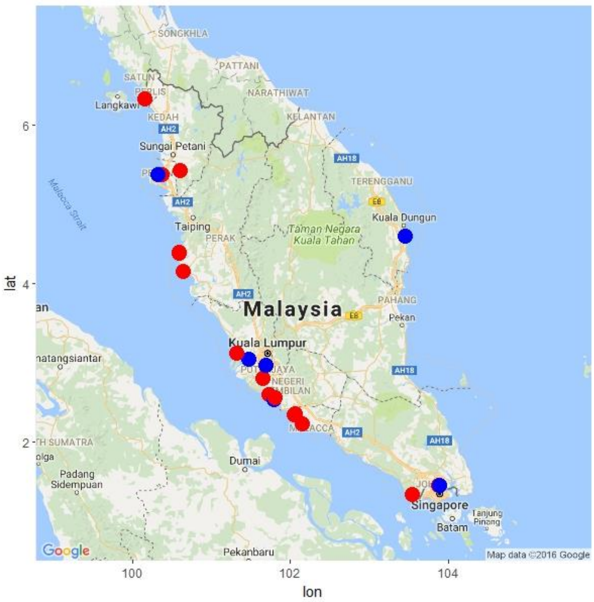


**Figure 1.** Locations of the national power producers (TNB) and the independent power producers (IPP) in Peninsular Malaysia, red points indicate the IPPs and blue points indicate the TNB.

### Data requirements for passenger cars

The passenger car is the preferred form of road transport in Malaysia [7]. Passenger cars are the primary sources of $NO_2$, CO [8], $CO_2$ [9], and $N_2O$ [10]. The World Bank Data reported that diesel and petrol make up 95% of total fuel consumed by the road transport sector. Hence, the emission inventory for passenger cars was developed from emission factors retrieved from international emission inventory guidelines and the published literature. The emission factor is the mass of pollutants emitted per car per fuel consumed by fuel-type (diesel or petrol) while the activity data is the fuel consumed and the number of active cars. Fuel consumption data is assumed to be the same with the amount of fuel sold.

The amount of fuel sold for 2009 to 2014 in Peninsular Malaysia was calculated based on the growth rate of active passenger cars in 2008 and the annual amount of fuel sold (obtained from the annual National Energy Balance of Malaysia reports). The growth rate based on the year 2008 (% per year) was calculated using Eq. (2),

$$Growthrate = \left[\frac{V_a - V_b}{V_b}\right] \times 100\% \quad (2)$$

where, $V_a$ is the total active passenger cars in a year, $V_b$ is the total active passenger car in 2008. The amount of fuel sold was calculated using Eq. (3),

$$Fuelsold_{i,p} = \left[\frac{GR_{n,p} \times Fuelsold_{i,m}}{GR_{n,m}}\right] \quad (3)$$

where, Fuel $sold_{i,p}$ is the estimated annual amount of fuel of type i (diesel or petrol) sold in Peninsular Malaysia, $GR_{n,p}$ is the growth rate of active passenger cars in year n (n = 2009, 2010, …, 2014) in Peninsular Malaysia, Fuel $sold_{i,m}$ is the annual amount of fuel of type i sold in Malaysia, and $GR_{n,p}$ is the growth rate of active passenger cars in year n in Peninsular Malaysia. The amount of fuel sold in Peninsular Malaysia had to be estimated from the total amount of fuel sold in Malaysia due to the limited data available in the National Energy Balance reports. Number of active passenger cars data was retrieved from the Department of Road Transport of Malaysia.

The vehicle kilometre travelled (VKT) activity data was calculated using Eq. (4) where it is a product of the annual average of vehicle kilometre travelled (AAVKT) for each state in Peninsular Malaysia and the total number of active passenger cars within each state.

$$VKT_S = [PC_S \times AAVKT_S] \tag{4}$$

where, $VKT_S$ is the vehicle kilometre travelled for the states in Peninsular Malaysia, $PC_s$ is the total number of active cars in the states in Peninsular Malaysia, and $AAVKT_S$ is the annual average vehicle kilometre travelled in the states in Peninsular Malaysia. The data for AAVKT were retrieved from [7] which is only available for the year 2013. Hence, only the emission inventory for 2013 was developed using VKT as the activity data.

The emission factor and the activity data were used to calculate the emission rates for the passenger cars. For the fuel consumption activity data, the emission factor with the amount of air pollutant emitted per amount of fuel consumed (gram per Giga-Joules) was used, while for the VKT activity data, the amount of air pollutant emitted per kilometre travelled (gram per kilometre) was used. The emission rates of air pollutants and greenhouse gases, $NO_X$, CO, $CO_2$, and $N_2O$, were then calculated.

## RESULTS

### Activity data and emission factors for power plants

The Energy Commission of Malaysia publishes reports on the list of power plants, the type of power plant, the type of fuel consumption, the licensed capacity, and the units of electricity generated in a year. Although these data are provided, there is no data on the fuel consumption of the power plant. Fuel consumption can be estimated for each power plant by using the units of electricity generated. Per the United States Energy Information Administration (U.S. EIA), there are two assumptions that can be made to calculate the amount of fuel consumption:

1. One kilowatt-hour (kWh) of electricity = 0.00052 metric tons of coal.
2. One kilowatt-hour (kWh) of electricity = 10.11 $ft^3$ of natural gas.

In this study, Net Calorific Value (NCV) of fuel was not used in the calculation of activity data, as the fuel consumption is already in the unit of tera-Joules per year [1]. Based on these assumptions, the amount of fuel combusted for coal and natural gas power plants and for the independent and national power producers were calculated and listed in Table 1.

**Table 1.** Fuel consumption for power plants using coal and natural gas and for the independent (IPP) and national power producers (TNB) in Peninsular Malaysia from 2008 to 2014.

| Year | Type of fuel | Fuel consumption (tera-Joules) | Type of power plant | Fuel consumption (tera-Joules) |
|---|---|---|---|---|
| 2008 | Coal | 63 614 | IPP | 505 547 |
| | Natural gas | 737 303 | TNB | 295 369 |
| 2009 | Coal | 71 016 | IPP | 462 345 |
| | Natural gas | 707 146 | TNB | 315 817 |
| 2010 | Coal | 93 844 | IPP | 476 197 |
| | Natural gas | 677 701 | TNB | 295 348 |
| 2011 | Coal | 103 850 | IPP | 486 916 |
| | Natural gas | 639 526 | TNB | 256 191 |
| 2012 | Coal | 109 889 | IPP | 503 803 |
| | Natural gas | 674 755 | TNB | 280 841 |
| 2013 | Coal | 106 542 | IPP | 565 716 |
| | Natural gas | 724 923 | TNB | 265 748 |
| 2014 | Coal | 109 951 | IPP | 544 357 |
| | Natural gas | 693 587 | TNB | 259 181 |

The highest fuel consumption and electricity generated for the TNB was in 2012 while for the IPP was in 2013. Although the role of IPP is to support the TNB, IPP generated more power than TNB due to the higher number of IPP plants.

Units of electricity generated are directly proportional to the amount of fuel combusted. It can be observed that the trends for the units generated and the fuel consumption was the same for both natural gas and coal. However, the amount needed for coal to generate electricity is different than that of natural gas. Even though the number of coal power plants in Peninsular Malaysia is a lot less than the natural gas power plant (four versus nineteen), including the combination of natural gas and diesel power plants, the coal power plant accounted for more than 30% of the total electricity generated. This is because the licensed capacities of the coal power plants were significantly higher than the natural gas power plants.

Default emission factors that are obtained from the Guidelines for Developing Emission Inventory in East Asia 2011 are used in calculating the emission rate as it is the highest emission factor compared to other guidelines. This gives the worst-case scenario for the air pollutants emitted. We found that the emission factor values for the coal were always larger than that of the natural gas. Thus, the emission of air pollutants from the coal power plant was higher than the natural gas power plant.

**Emission inventory for power plants**

Emission rates for each of the air pollutants and greenhouse gases – $SO_2$, $NO_X$, $PM_{10}$, $PM_{2.5}$, CO, and $CO_2$ – are estimated using the "simple" method based on the activity data (i.e., fuel consumption) and default emission factors from the Guidelines for Developing Emission Inventory in East Asia 2011.

Table 2 lists the emission inventory for the type of fuel used and type of power plant, respectively. Based on the table, the coal power plants emitted a higher amount of pollutants than natural gas as the coal emission factors were larger than the natural gas. Except for the year 2013, the mass of air pollutants emitted by the coal power plants was the same for all pollutants and showed a gradual increase with the year. Conversely, the emissions from the natural gas power plant decreased with the year. Thus, the coal power plant and natural gas power plant were correlated because both power plants need to cater to the nation's electricity demands. The emission factors of $PM_{10}$ and $PM_{2.5}$ for natural gas are the same, which are 0.9 and 0.89 gram $GJ^{-1}$, respectively and therefore no difference regarding emission rates was observed. As for the type of plants, IPP emitted more air pollutants compared to TNB because the number of IPP power plants was greater than the number of TNB power plants.

The pollutant with the lowest emission rate was $SO_2$ from the TNB gas-fired power plant, but the pollutant with the highest emission rate was also $SO_2$ but from the IPP power plants. This is because the IPP has both coal- and gas-fired power plants, and the emission factors between the coal and gas power plants vary widely. IPP was the main contributor to air pollution as it had both coal and natural gas power plants. The lower emission factors of natural gas undermined the fact that the number of the natural gas power plants was larger than the coal power plants.

The highest emission rate of criteria pollutants was recorded in the year of 2012. But for the greenhouse gas ($CO_2$), the highest emission rate was recorded in 2013. Per the U.S. Energy Information Administration [11], the least amount of $CO_2$ released for an equivalent amount of energy production is the natural gas. Again, due to the large number of natural gas power plants in the Peninsular Malaysia, the highest contributor to $CO_2$ emissions was the natural gas power plants.

**Table 2.** Emission inventory for the coal and natural gas power plants and for the independent and national power producers in the Peninsular Malaysia from 2008 to 2014.

| Year | Coal power plants (metric tons per year) | | | | | | Natural gas power plants (metric tons per year) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SO_2$ | $NO_X$ | $PM_{10}$ | $PM_{2.5}$ | CO | $CO_2$ | $SO_2$ | $NO_X$ | $PM_{10}$ | $PM_{2.5}$ | CO | $CO_2$ |
| 2008 | 52 163 | 19 720 | 1 272 | 573 | 9 542 | 6 113 273 | 221 | 65 620 | 664 | 664 | 28 755 | 41 362 690 |
| 2009 | 58 233 | 22 015 | 1 420 | 639 | 10 652 | 6 824 615 | 212 | 62 936 | 636 | 636 | 27 579 | 39 670 902 |
| 2010 | 76 952 | 29 092 | 1 877 | 845 | 14 077 | 9 018 423 | 203 | 60 315 | 610 | 610 | 26 430 | 38 019 009 |
| 2011 | 84 936 | 32 110 | 2 072 | 932 | 15 537 | 9 954 041 | 192 | 56 918 | 576 | 576 | 24 942 | 35 877 424 |
| 2012 | 90 109 | 34 066 | 2 198 | 989 | 16 483 | 10 560 342 | 202 | 60 053 | 607 | 607 | 26 315 | 37 853 750 |
| 2013 | 87 364 | 33 028 | 2 131 | 959 | 15 981 | 10 238 676 | 218 | 64 518 | 652 | 652 | 28 272 | 40 668 155 |
| 2014 | 90 160 | 34 085 | 2 199 | 990 | 16 493 | 10 566 253 | 208 | 61 729 | 624 | 624 | 27 050 | 38 910 232 |
| Year | Independent power producers (metric tons per year) | | | | | | National power producers (metric tons per year) | | | | | |
| | $SO_2$ | $NO_X$ | $PM_{10}$ | $PM_{2.5}$ | CO | $CO_2$ | $SO_2$ | $NO_X$ | $PM_{10}$ | $PM_{2.5}$ | CO | $CO_2$ |
| 2008 | 52 296 | 59 052 | 1 670 | 970 | 26 778 | 30 905 749 | 89 | 26 288 | 266 | 266 | 11 519 | 16 570 214 |
| 2009 | 58 350 | 56 843 | 1 773 | 991 | 25 914 | 28 778 176 | 95 | 28 108 | 284 | 284 | 12 317 | 17 717 341 |
| 2010 | 77 067 | 63 121 | 2 221 | 1 189 | 28 989 | 30 468 415 | 89 | 26 286 | 266 | 266 | 11 519 | 16 569 017 |
| 2011 | 85 051 | 66 227 | 2 417 | 1 277 | 30 487 | 31 459 164 | 77 | 22 801 | 231 | 231 | 9 991 | 14 372 301 |
| 2012 | 90 227 | 69 124 | 2 552 | 1 344 | 31 846 | 32 658 895 | 84 | 24 995 | 253 | 253 | 10 953 | 15 755 197 |
| 2013 | 87 502 | 73 895 | 2 544 | 1 372 | 33 889 | 35 998 366 | 80 | 23 652 | 239 | 239 | 10 364 | 14 908 465 |
| 2014 | 90 290 | 72 747 | 2 590 | 1 381 | 33 434 | 34 936 435 | 78 | 23 067 | 233 | 233 | 10 108 | 14 540 050 |

**Activity data and emission factors for passenger cars**

The amount of fuel consumed by passenger cars was calculated using Eq. (3) and the results are shown in **Table 3**. The growth rate of active passenger cars increased over the years; hence the increase in fuel consumed. Most of the fuel consumption of passenger cars were of type petrol because only a small percentage of passenger cars use diesel. The usage of diesel is generally for hybrid, large-capacity engine, and high-technology cars, which accounts for a small fraction of the total number of active cars.

Table 4 lists the vehicle kilometre travelled (VKT) for passenger cars in each state in the Peninsular Malaysia in 2013 calculated using Eq. (4). The table shows that the highest number of VKT for the year 2013 was Kuala Lumpur, which was $1.18\times10^{11}$ kilometres. Selangor recorded the second largest VKT followed by Pulau Pinang and Johor. The smallest VKT was from Perlis because it is the smallest state and the least developed. The range of annual average vehicle kilometre travelled (AAVKT) in developed countries is between 10 000 and 18 000 kilometres per car [12]. The states of Johor, Kedah, and Perlis were within this range.

**Table 3.** Estimated fuel consumption activity data for passenger cars in Peninsular Malaysia for 2008-2014.

| Year | Type of fuel | Fuel consumption (tera-Joules) |
|---|---|---|
| 2008 | Petrol<br>Diesel | 353 000<br>212 000 |
| 2009 | Petrol<br>Diesel | 377 000<br>220 000 |
| 2010 | Petrol<br>Diesel | 411 000<br>203 000 |
| 2011 | Petrol<br>Diesel | 343 000<br>265 000 |
| 2012 | Petrol<br>Diesel | 367 000<br>239 000 |
| 2013 | Petrol<br>Diesel | 529 000<br>280 000 |
| 2014 | Petrol<br>Diesel | 521 000<br>350 000 |

**Table 4.** Vehicles kilometre travelled (VKT) for passenger cars in each state in the Peninsular Malaysia in 2013.

| State | Number of active passenger cars [a] | Annual average vehicle kilometre travelled [b] AAVKT (kilometres per car) | Vehicle kilometre travelled $VKT\times10^9$ kilometres |
|---|---|---|---|
| Perlis | 71 505 | 25 953 | 1.86 |
| Kedah | 781 143 | 22 692 | 17.70 |
| Pulau Pinang | 1 797 153 | 20 980 | 37.70 |
| Perak | 1 429 589 | 24 933 | 35.60 |
| Selangor | 1 709 452 | 28 576 | 48.90 |
| Kuala Lumpur | 4 620 264 | 25 570 | 118.00 |
| Negeri Sembilan | 567 574 | 24 620 | 14.00 |
| Melaka | 543 866 | 23 552 | 12.80 |
| Johor | 2 283 489 | 16 342 | 37.30 |
| Pahang | 641 885 | 27 919 | 17.90 |
| Terengganu | 414 316 | 23 461 | 9.72 |
| Kelantan | 554 596 | 22 601 | 12.50 |

[a] Department of Road Transport of Malaysia
[b] Car annual vehicle kilometre travelled estimated from the car manufacturers' data [7]

Default emission factors were used to calculate emission rates of passenger cars. These factors were retrieved from the Guidelines for Developing Emission Inventory in East Asia 2011 and the Intergovernmental Panel on Climate Change (IPCC). Emission factors vary with each type of fuel and activity data. Vehicles kilometre travelled, the total number of active passenger cars and the fuel standard are needed to develop the emission inventory. The fuel standard in the year 2013 was the "Euro 4" standard [13].

**Emission inventory for passenger cars**

The emission inventory for passenger cars is developed for air pollutants and greenhouse gases – CO, $NO_X$, $CO_2$, and $N_2O$ – based on the amount of fuel consumed and the vehicle kilometre travelled activity data using default emission factors. Table 5 lists the emission inventory for the petrol and diesel passenger cars for the Peninsular Malaysia from 2008 to

2014, using fuel consumption as the activity data. The table shows that the highest gas emitted was the petrol passenger car for $CO_2$ followed by CO, 36.7 metric tons and 1.18 metric tons in 2013, respectively. $N_2O$ contributed the smallest amount to the total emission, which was not more than 350 metric tons per year. However, its trend was increasing with year. $NO_X$ emissions were higher than $N_2O$ but lower than $CO_2$ and CO. The trend increased from 2008 to 2010 but suddenly dropped in 2011 until 2013. This might be due to the decreased fuel consumed caused by the MYR0.50 increase in petrol price. We found that the diesel passenger car also had the same trend as the petrol passenger car but with less pollutants emitted to the atmosphere.

For the emission inventory using the vehicle kilometre travelled as the activity data, the passenger car emission inventory is listed in Table 6 for the year 2013. Regarding the emissions, it has the same trend as the emission inventory using the fuel consumed activity data. Most of the pollutants emitted were $CO_2$, followed by CO, $NO_X$, and $N_2O$. For both fuel type, Kuala Lumpur was the largest contributor to air pollution as it has the highest number of active passenger cars.

**Table 5.** The emission inventory for the petrol and diesel passenger car for the Peninsular Malaysia from 2008 to 2014 using fuel consumption as the activity data.

| Year | Petrol passenger cars (metric tons) | | | | Diesel passenger cars (metric tons) | | | |
|---|---|---|---|---|---|---|---|---|
| | CO | $NO_X$ | $N_2O$ | $CO_2$ | CO | $NO_X$ | $N_2O$ | $CO_2$ |
| 2008 | 786 000 | 1 130 | 212 | 24 500 000 | 20 600 | 827 | 127 | 15 700 000 |
| 2009 | 840 000 | 1 210 | 226 | 26 100 000 | 21 400 | 858 | 132 | 16 300 000 |
| 2010 | 915 000 | 1 320 | 247 | 28 500 000 | 19 700 | 792 | 122 | 15 000 000 |
| 2011 | 764 000 | 1 100 | 206 | 23 800 000 | 33 300 | 1 340 | 160 | 25 400 000 |
| 2012 | 817 000 | 1 170 | 220 | 25 400 000 | 23 200 | 1 160 | 143 | 17 700 000 |
| 2013 | 1 180 000 | 1 700 | 317 | 36 700 000 | 27 200 | 1 090 | 168 | 20 700 000 |
| 2014 | 1 160 000 | 1 670 | 313 | 36 100 000 | 34 000 | 1 370 | 210 | 26 000 000 |

**Table 6.** The emission inventory for the petrol and diesel passenger car for the Peninsular Malaysia from 2008 to 2014 using vehicle kilometre travelled as the activity data.

| State | Petrol passenger cars (metric tons) | | | | Diesel passenger cars (metric tons) | | | |
|---|---|---|---|---|---|---|---|---|
| | CO | $NO_X$ | $N_2O$ | $CO_2$ | CO | $NO_X$ | $N_2O$ | $CO_2$ |
| Perlis | 1 220 | 115 | 9 | 430 000 | 19 | 180 | 1 120 | 430 000 |
| Kedah | 11 600 | 1 100 | 89 | 4 050 000 | 117 | 1 720 | 10 600 | 4 050 000 |
| Pulau Pinang | 24 800 | 2 340 | 189 | 8620 000 | 377 | 3 660 | 22 700 | 8 620 000 |
| Perak | 23 400 | 2 210 | 178 | 8140 000 | 356 | 3 450 | 21 396 | 8 140 000 |
| Selangor | 32 200 | 3 030 | 245 | 11 200 000 | 490 | 4 740 | 29 400 | 11 200 000 |
| Kuala Lumpur | 77 600 | 7 320 | 590 | 27 000 000 | 1 180 | 11 400 | 71 000 | 27 000 000 |
| Negeri Sembilan | 9 210 | 868 | 70 | 3 200 000 | 140 | 1 360 | 8 410 | 3 200 000 |
| Melaka | 8 420 | 794 | 64 | 2 930 000 | 128 | 1 240 | 7 690 | 2 930 000 |
| Johor | 24 500 | 2 310 | 187 | 8 530 000 | 373 | 3 620 | 22 400 | 8 530 000 |
| Pahang | 11 800 | 1 110 | 90 | 4 090 000 | 179 | 1 740 | 10 800 | 4 090 000 |
| Terengganu | 6 400 | 603 | 49 | 2 220 000 | 97 | 943 | 5 840 | 2 220 000 |
| Kelantan | 8 230 | 775 | 63 | 2 880 000 | 125 | 1 210 | 7 510 | 2 880 000 |

## CONCLUSIONS

The emission inventory for the stationary fuel combustion was developed using the simple method, where the air pollutant emission rates are calculated using the activity data and the default emission factor. We employed the emission factors from the East Asia Guideline as it would give the worst-case air pollution scenario. The emission inventory for the passenger cars was developed using the combination of default emission factors and total active passenger cars, the annual amount of fuel sold, the annual growth rate, and the vehicle kilometre travelled as the activity data. Emission from petrol passenger cars contributed the most to air pollution compared to diesel passenger cars as petrol is more widely used than diesel. Kuala Lumpur was the principal source of air pollution due to the high vehicle kilometre travelled and the number of active passenger cars. Passenger cars emitted, for petrol, 36.2 mega-metric tons per year of pollutants while, for diesel, 26 mega-metric tons per year of pollutants. The total emission rate of the criteria air pollutants and the greenhouse gases ($SO_2$, $NO_X$, $PM_{10}$, $PM_{2.5}$, CO, and $CO_2$) from the independent power producers were higher compared to the national power producers, which were 35.1 mega-metric tons per year and 14.6 mega metric tons per year, respectively. This is due to the large quantity of the independent power producers in Peninsular Malaysia. Moreover, the independent power producers had both types of power plants, coal- and gas-fired. Finally, we projected that by 2020 (based on the year 2008), power plants will emit 56.5 mega-metric tons per year of $SO_2$, $NO_X$, $PM_{10}$, $PM_{2.5}$, CO, and $CO_2$ at a cumulative growth rate of 15.6%. Passenger cars will emit 122.9 mega-metric tons per year of $NO_X$, CO, $CO_2$, and $N_2O$ at a cumulative growth rate of 67.2%.

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