KEMENTERIAN TENAGA, SAINS, TEKNOLOGI, ALAM SEKITAR DAN PERUBAHAN IKLIM
MINISTRY OF ENERGY, SCIENCE, TECHNOLOGY, ENVIRONMENT & CLIMATE CHANGE

# 2017 CDM ELECTRICITY BASELINE FOR MALAYSIA

Prepared by Malaysian Green Technology Corporation

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# LIST OF ACRONYMS

| | |
|---|---|
| GHG | Greenhouse Gases |
| MESTECC | Ministry of Energy, Science, Technology, Environment and Climate Change |
| CDM | Clean Development Mechanism |
| EC | Energy Commission (Suruhanjaya Tenaga) |
| SEB | Sarawak Energy Berhad |
| SESB | Sabah Electricity Sdn Bhd |
| SEDA | Sustainable Energy Development Authority |
| TNB | Tenaga Nasional Berhad |
| UNFCCC | United Nation Framework Convention on Climate Change |
| IPCC | Intergovernmental Panel on Climate Change |
| $CO_2$ | Carbon Dioxide |
| CM | Combined Margin |
| OM | Operating Margin |
| BM | Built Margin |
| FiT | Feed-in Tariff |
| NCV | Net Calorific Value |
| LCMR | Low Cost/ Must-run |
| LASL | Lowest Annual System Loads |
| OCGT | Open Cycle Gas Turbine |
| CCGT | Combined Cycle Gas Turbine |
| ktoe | Kilo tonnes of oil equivalent |

# 1. INTRODUCTION

Greenhouse gases (GHG) can be measured by recording emissions at source by estimating the amount emitted using activity data (e.g. the amount of fuel used) and applying relevant conversion factors. The emission factors allow organizations and individuals to calculate GHG emissions from a range of activities, including energy use.

As a non-Annex 1 party to the United Nations Framework Convention on Climate Change UNFCCC), Malaysia has estimated GHG emission factors for grid connected electricity since 2005. **CDM Electricity Baseline** will be used for CDM energy projects in Malaysia to calculate their carbon emissions and potential carbon emissions reduction from mitigation actions.

The **Government** considers the environment to be an integral component for sustainable development and will work to achieve the protection and improvement of the use of natural resources in a sustainable manner. Identifying the sources of emissions is essential for the development of effective measures to reduce greenhouse gas (GHG) emissions and ambient air pollution, as well as for the development of green technology or clean air action plans.

The **Ministry of Energy, Science, Technology, Environment and Climate Change (MESTECC)** appointed Malaysian Green Technology Corporation (GreenTech Malaysia) as the consultant to conduct a study to update the Malaysian grid electricity energy-related carbon emission factors for 2017. GreenTech Malaysia has undertaken this study since 2005, to support project developers in calculating Certified Emission Reduction (CERs) generated from *Clean Development Mechanism* (CDM) projects under the Kyoto Protocol. All CDM projects that involve electricity generation or consumption must use an emission factor representing the quantity of GHGs emitted per unit of electricity generated. Accurate Malaysian Grid Emission Factors are necessary to enable the Malaysian DNA (Designed National Authority) to review and, as appropriate, to approve CDM project applications. Subsequently, the grid electricity emission factors for all three regions have been updated annually until 2017.

Climate change is widely considered as the biggest environmental challenge facing the world today and is increasingly dominating international and local political agendas. Pressure is mounting on governments to act to reduce greenhouse gas (GHG) emissions. MESTECC and other relevant ministries are actively promoting low emissions activities, investments, advocating GHG emissions reduction programmes, establishing the national GHG inventory, encouraging capacity building and outreach for stakeholders including the government and private sectors as well as promoting sustainable development and business.

Table 1 below shows the CDM Electricity Baseline's emission factors for Malaysia that have been used to calculate CDM project emissions and were also used as 'national emission factor' to calculate the emissions associated with mitigation measures that saves electricity. Table 1 below shows the emission factors from 2005 to 2016 for all three grids.

**Table 1: CDM Electricity Baseline's emission factor for Malaysia**

| CDM Electricity Baseline's Emission Factors ($tCO_2/MWh$) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Regions** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** |
| **Peninsular Malaysia** | 0.614 | 0.661 | 0.684 | 0.672 | 0.683 | 0.760 | 0.747 | 0.741 | 0.742 | 0.694 | 0.659 | 0.667 |
| **Sabah** | 0.745 | 0.801 | 0.807 | 0.651 | 0.612 | 0.574 | 0.531 | 0.546 | 0.533 | 0.536 | 0.572 | 0.551 |
| **Sarawak** | 0.956 | 0.928 | 0.873 | 0.825 | 0.805 | 0.847 | 0.841 | 0.872 | 0.724 | 0.699 | 0.421 | 0.364 |

*Source: Malaysian Green Technology Corporation*

To establish the emission factors, GreenTech Malaysia sourced data from relevant agencies such as Energy Commission (EC), Sabah Electricity Sdn. Bhd. (SESB) and Sarawak Energy Berhad (SEB). Supporting data were also obtained from Single Buyer, Sustainable Energy Development Authority (SEDA) and from other relevant stakeholders.

## 1.1 Objectives

The main objectives of this study are:

- To update the current electricity emission baseline for Malaysia using the approved baseline methodology and the most recent data available for the electricity sector.

- To report and publish the grid connected electricity emission factors for Peninsular Malaysia, Sabah and Sarawak for use when calculating current GHG emissions and potential emissions reduction through mitigation actions.

## 1.2 Scope of the Study

In conducting the study, GreenTech Malaysia focuses on several key areas including:

- **Project boundary**: Review 2017 grid electricity systems. Individual emission factors will be established for grid electricity systems of the three (3) regions, namely, Peninsular Malaysia, Sabah and Sarawak for 2017.

- **Spatial Extent:** Determine which power plants were physically connected to the electricity grid system (without transmission constraints) within the boundary in

2017.

- **Emission sources**: Include all relevant power plants that emitted GHG from electricity generation in 2017.

- **Emission inventory**: Generate information and data based on the latest calculation methodology such as information on electricity generation and fuel consumption of power plants for 2017, including the plant efficiency and load hours information from all three regions.

# 2. METHODOLOGY

## 2.1 Selection of Methodology

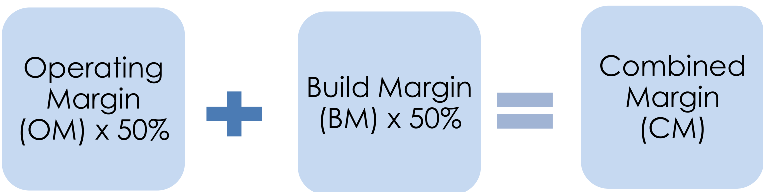
This study used Methodological Tool 7: Tool to calculate the emission factor for an electricity system, Version 7.0 to calculate the emission factor for all three regions in Malaysia. In this reporting, the methodology has been assessed based on the method of calculation and data requirements.

## 2.2 Methodological Tool 7: Tool to calculate the emission factor for an electricity system

This tool is applied to estimate the OM, BM and CM when calculating baseline emissions for a project activity that substitutes grid electricity that is where a project activity supplies electricity to a grid or a project activity that results in savings of electricity that would have been provided by the grid (e.g. demand-side energy efficiency projects). **Combined Marginal (CM) Emission factors** is the result of a weighted average of two emission factors pertaining to the electricity system; the operating margin and build margin: -

1. **'Operating Margin' (OM)** – this refers to the cohort of the power plants that would reduce or increase their electricity generation in response to changes in demand due to the proposed project activity.

2. **'Build Margin' (BM)** - this refers to the cohort of power plants whose construction and future operation would be affected by the proposed project activity.




The UNFCCC methodology proposes four approaches to calculate an **Operating Margin (OM**) (see the flow chart in Figure 1) emission factor: -

1. **Simple operating margin**
   Generation weighted emissions averaged of all power plants serving the system excluding low cost/must-run (LCMR).

LCMR are defined as power plants with low marginal generation costs or dispatched independently of the daily or seasonal load of the grid. They include hydro, geothermal, wind, low-cost biomass, nuclear and solar generation. If a fossil fuel plant is dispatched independently of the daily or seasonal load of the grid and if this can be demonstrated based on the publicly available data, it should be considered as a LCMR.

2. **Simple adjusted operating margin**
   Variation of the simple OM for systems where low cost/must-run plant operates for a proportion of the year at the margin.

3. **Dispatch data analysis operating margin**
   Based on the grid power units that are dispatched at the margin.

4. **Average operating marginal**
   Generation weighted average emission rate of all power plants serving the grid including low-cost/must-run power plants.

The **Build Margin (BM)** is calculated as the generation weighted average emission factor of the set of power units below: -

- set of five power units that have been built most recently
  **OR**
- set of power units that comprise at least 20% of the system generation.

Any power units older than 10 years will be excluded from the set of power units and include the registered CDM projects that supply electricity to the grid most recently.

The **Combined Margin (CM)** emission factor is calculated by combining the operating margin and build margin. The default assumption for the weighting of these two factors is a 50-50 average. An alternative weighting can be applied if this can be justified by the type of project.

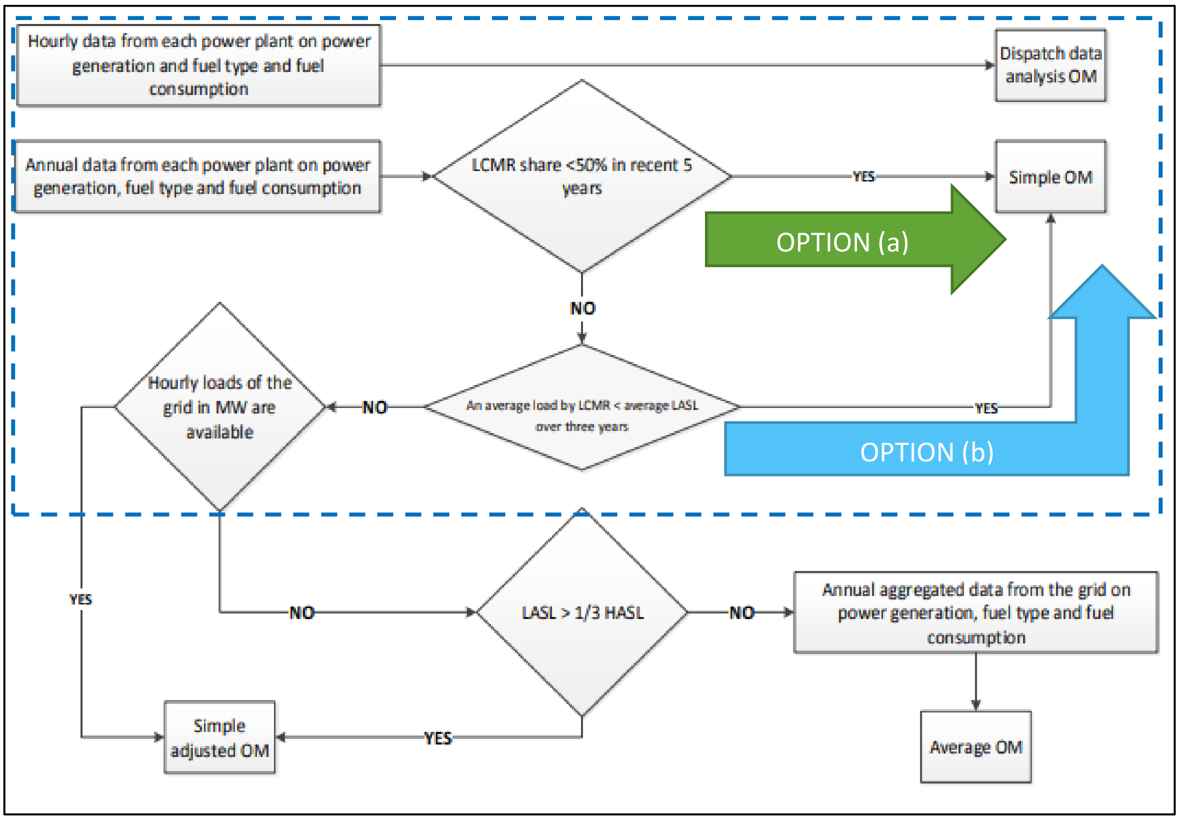
**<u>Determining the Operating Margin (OM) & calculation equations</u>**

The Operating Margin (OM) will be calculated based on one of the following methods:

- Simple OM; or
- Simple Adjusted OM; or
- Dispatch Data Analysis OM; or
- Average OM.

Figure 1 below shows the flow chart on the application of method selection for OM.

**Figure 1: Flow chart on the Operating Margin (OM) method selection**




For this study, the selected method to calculate the OM for all regions are based on Simple OM. Selection of Simple OM will be based on two option as follows:

- **Option (a)** is when the Low Cost Must Run (LCMR) shares less than 50% in most recent 5 years. LCMR are defined as power plants with low marginal generation costs or dispatched independently of the daily or seasonal load of the grid and if this can be demonstrated based on the publicly available data, it should be considered as a low-cost/must-run.

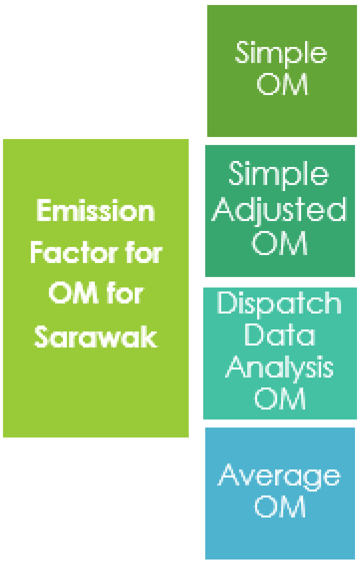
  - **Energy generation from LCMR sources for Peninsular Malaysia and Sabah are still less than 50% in most recent 5 years and thus satisfied the following requirement under Option (a).**


***Why Simple OM (Option A1 equation) is chosen?***

- ✓ *Annual data from each power plant on power generation, fuel type and fuel consumption*
- ✓ *Low-cost /must-run resources constitute less than 50% of total grid generation in most recent 5 years (excluding electricity generated by off-grid power plants)*

- **Option (b)** is when the average load of LCMR is less than average value of Lowest Annual System Load (LASL) over three years. According to the guideline, LASL is the minimum recorded value of hourly load in MW in a grid over a calendar year.

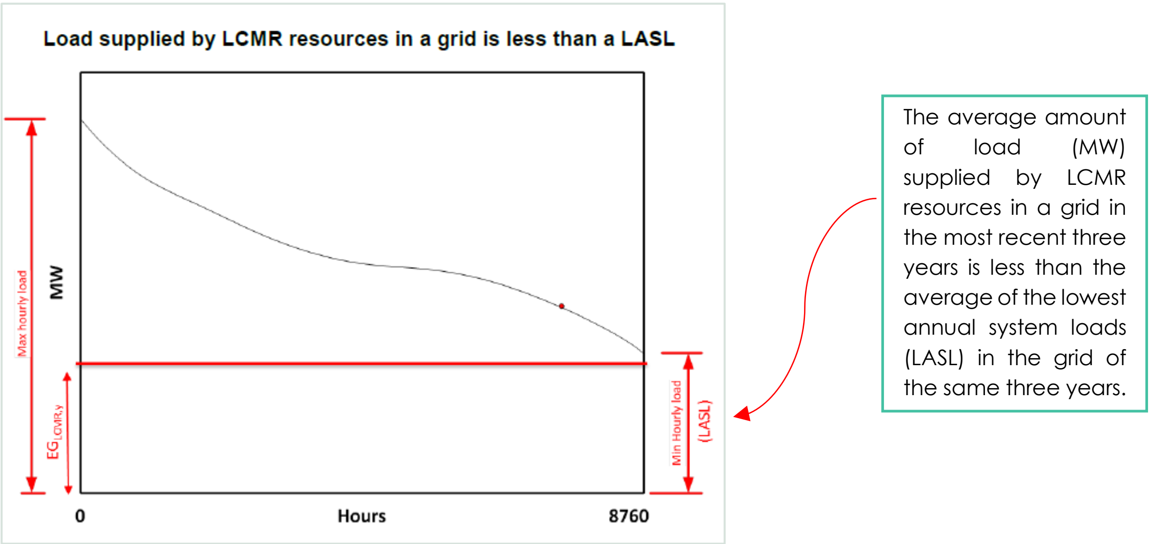
    - **The LCMR share in Sarawak is more than 50% in most recent three years. However, based on data provided by SEB, the average LCMR is still less than average value of LASR over three years and thus satisfied the following requirement under Option (b).**




***Why Simple OM and not Simple Adjusted OM is chosen for Sarawak?***

- ✓ *Even though low-cost /must-run resources constitute more than 50% of total grid generation in most recent 5 years, the average load supplied by low-cost /must-run in the grid is still less than the lowest annual system loads (LASL) in the grid over three years.*

The average load supplied by LCMR in the grid is plotted in a horizontal line across load duration curve such that the area under the curve (MW times hours) equals the total generation (in MWh) from LCMR. If the lines do not intersect, then one may exclude LCMR from OM calculation.




Figures below show the LCMR generation capacity for Peninsular Malaysia, Sabah and Sarawak.

**Figure 2: LCMR generation capacity for Peninsular Malaysia**

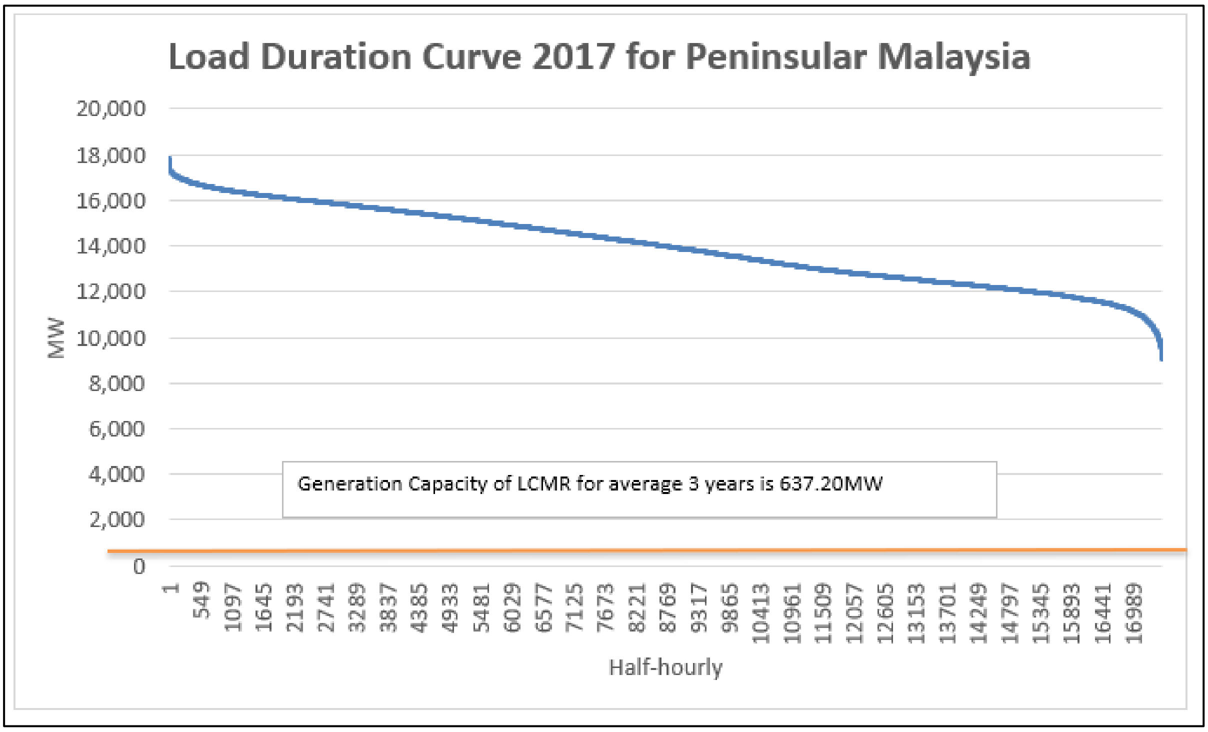


**Figure 3: LCMR generation capacity for Sabah**

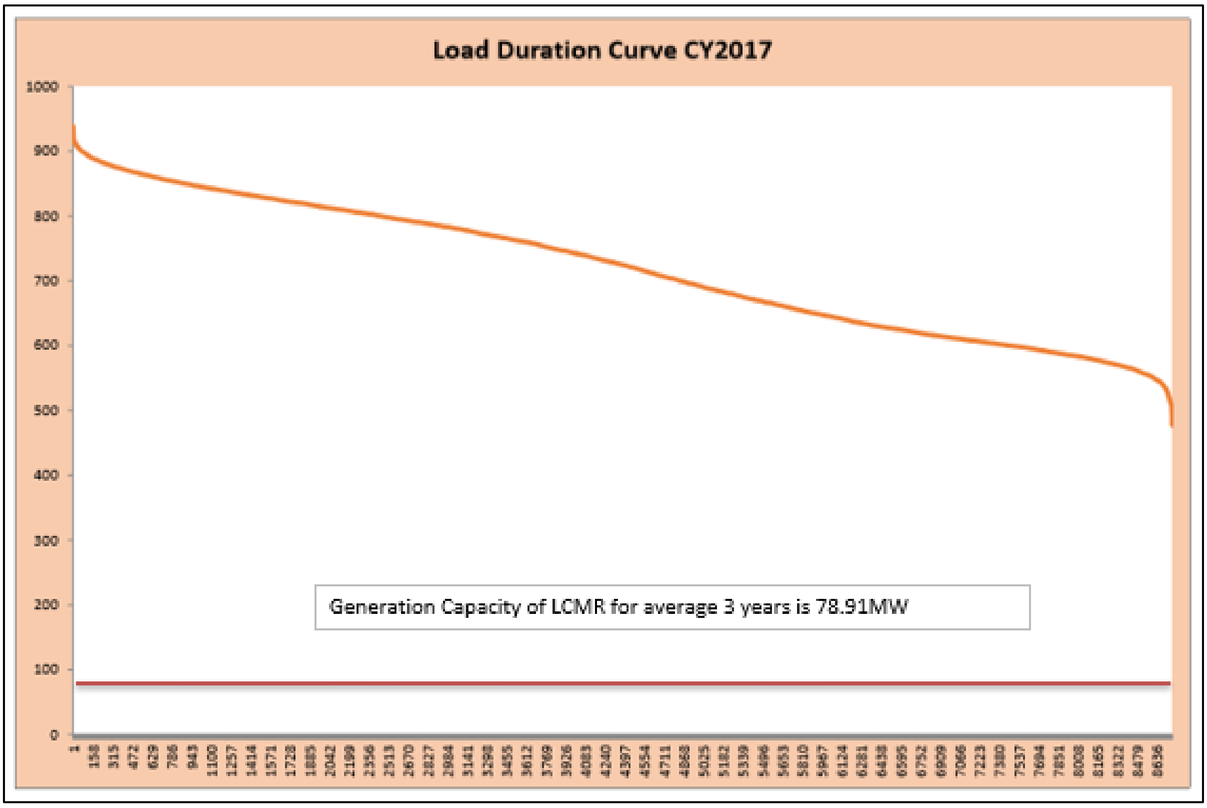
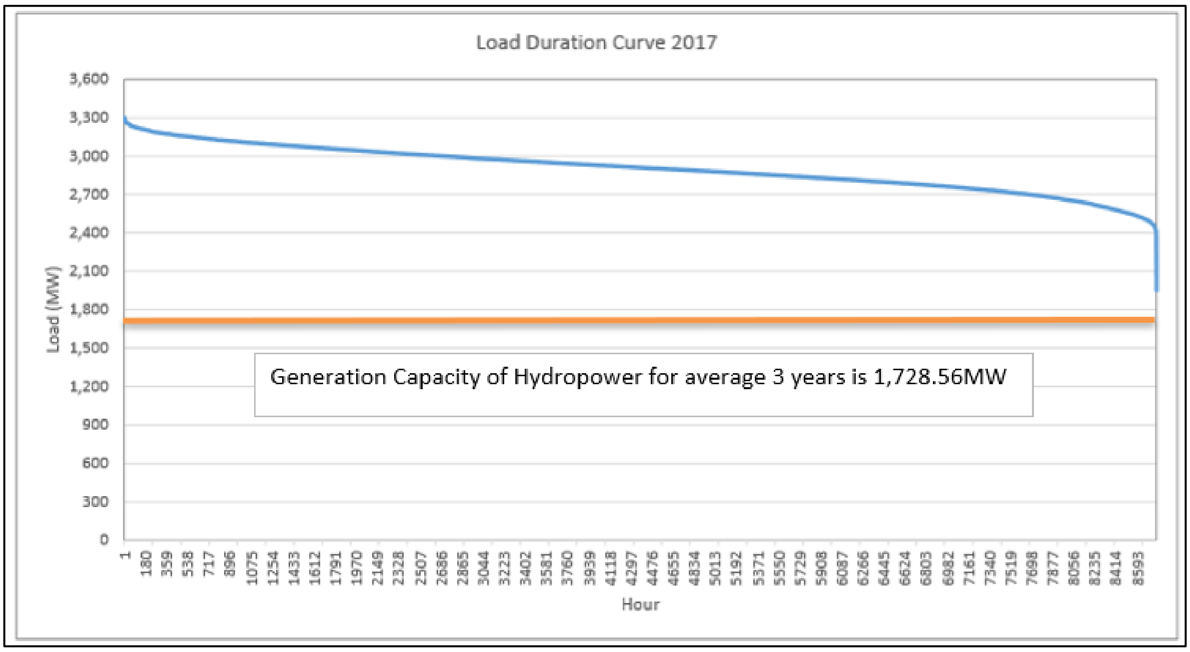



**Figure 4: LCMR generation capacity for Sarawak**




The off-grid power plants in the electricity system is not included in the calculation of emission factor due to the following reasons:

1. There is ***NO*** load shedding programme in place to compensate the deficit of the generation capabilities.
2. The total capacity of off-grid power plants (in MW) is less than 10% of the total capacity of grid power plants in the electricity system.

**Figure 5: Equations used for Operating Margin (OM)**

**Option A**

The Simple OM emission factor is calculated based on the net electricity generation of each power plant unit and an emission factor to each power unit.

$$EF_{grid,OMsimple,y} = \frac{\sum_m EG_{m,y} \times EF_{EL,m,y}}{\sum_m EG_{m,y}}$$

Where:

| | | |
|---|---|---|
| $EF_{grid,OMsimple,y}$ | = | Simple operating margin $CO_2$ emission factor in year *y* (t $CO_2$/MWh) |
| $EG_{m,y}$ | = | Net quantity of electricity generated and delivered to the grid by power unit *m* in year *y* (MWh) |
| $EF_{EL,m,y}$ | = | $CO_2$ emission factor of power unit *m* in year *y* (t $CO_2$/MWh) |
| *m* | = | All power units serving the grid in year *y* except low-cost/must-run power units |
| *y* | = | The relevant year as per the data vintage chosen |

**Option A1**

If for power unit m only data on fuel consumption and electricity generation is available, the emission factor should be determined as shown.

$$EF_{EL,m,y} = \frac{\sum_i FC_{i,m,y} \times NCV_{i,y} \times EF_{CO2,i,y}}{EG_{m,y}}$$

Where:

| | | |
|---|---|---|
| $EF_{EL,m,y}$ | = | $CO_2$ emission factor of power unit *m* in year *y* (t $CO_2$/MWh) |
| $FC_{i,m,y}$ | = | Amount of fuel type *i* consumed by power unit *m* in year *y* (Mass or volume unit) |
| $NCV_{i,y}$ | = | Net calorific value (energy content) of fuel type *i* in year *y* (GJ/mass or volume unit) |
| $EF_{CO2,i,y}$ | = | $CO_2$ emission factor of fuel type *i* in year *y* (t $CO_2$/GJ) |
| $EG_{m,y}$ | = | Net quantity of electricity generated and delivered to the grid by power unit *m* in year *y* (MWh) |
| *m* | = | All power units serving the grid in year *y* except low-cost/must-run power u nits |
| *i* | = | All fuel types combusted in power unit *m* in year *y* |

**Option A2**

If for power unit m only data on electricity generation and the fuel types used is available, the emission factor should be determined based on the $CO_2$ emission factor of the fuel type used and the efficiency of the power plant.

$$EF_{EL,m,y} = \frac{EF_{co2,m,i,y} \times 3.6}{\eta_{m,y}}$$

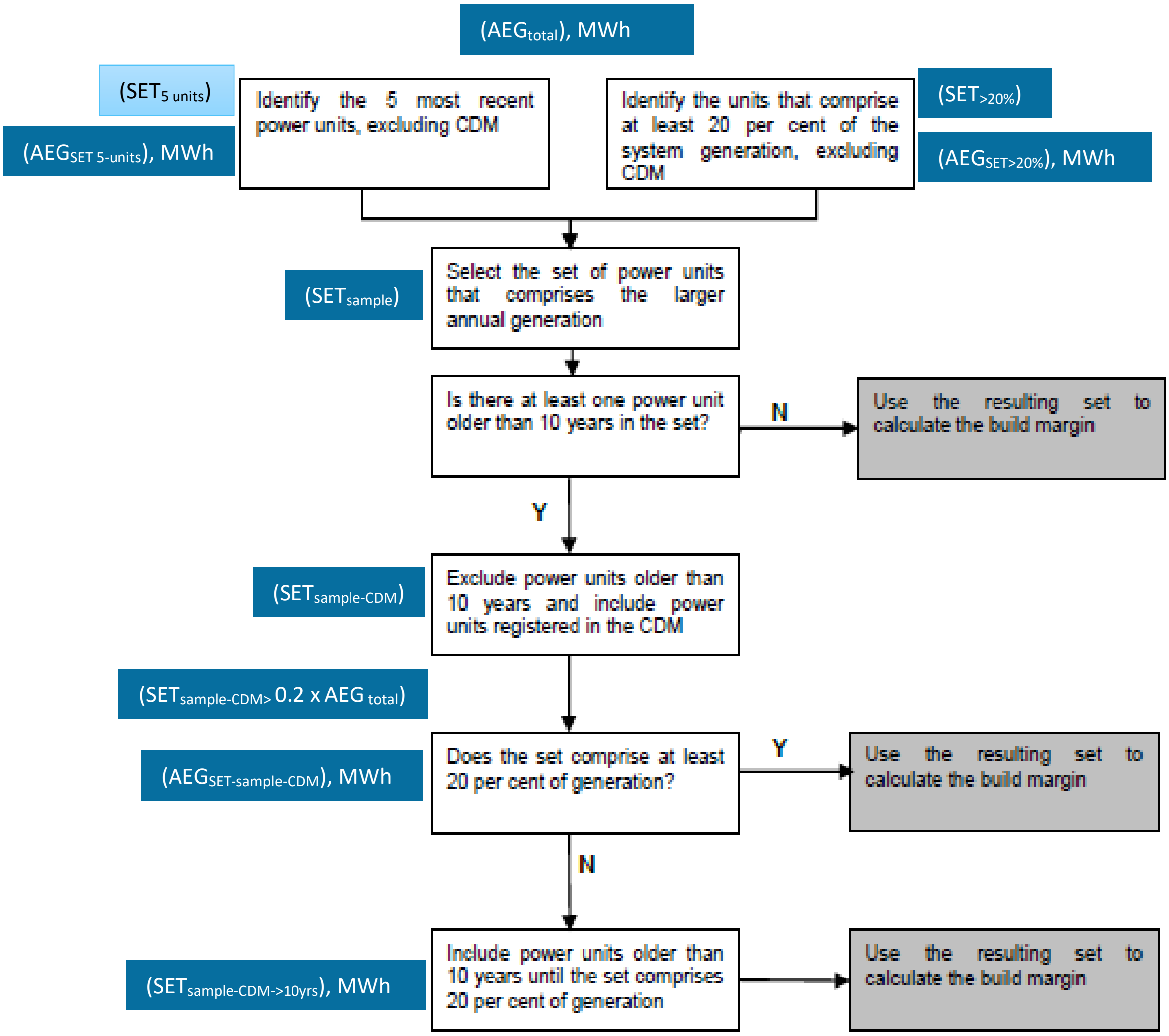
Where:

| | | |
|---|---|---|
| $EF_{EL,m,y}$ | = | $CO_2$ emission factor of power unit *m* in year *y* (t $CO_2$/MWh) |
| $EF_{CO2,m,i,y}$ | = | Average $CO_2$ emission factor of fuel type *i* used in power unit *m* in year *y* (t $CO_2$/GJ) |
| $\eta_{m,y}$ | = | Average net energy conversion efficiency of power unit *m* in year *y* (ratio) |
| *m* | = | All power units serving the grid in year *y* except low-cost/must-run power units |
| *y* | = | The relevant year as per the data vintage chosen |

**Determining the Build Margin (BM) & Calculation Equations**

To calculate the build margin (BM) emission factor, the set of power units is chosen based on the procedure shown in Figure 6 below. ($EF_{grid,BM,y}$).

**Figure 6: Procedure of determining the sample group of power units**




The Set sample for all three regions will be chosen based on updated data on newly built power plants.

The build margin emission factor is the generation-weighted average emission factor ($tCO_2/MWh$) of all power units *m* during the most recent year *y* for which electricity generation data is available is calculated as in Figure 7 below:

**Figure 7: The Build Margin equation**

$$EF_{grid,BM,y} = \frac{\sum_m EG_{m,y} \times EF_{EL,m,y}}{\sum_m EG_{m,y}}$$

Where:

| | | |
|---|---|---|
| $EF_{grid,BM,y}$ | = | Build margin $CO_2$ emission factor in year *y* (t $CO_2$/MWh) |
| $EG_{m,y}$ | = | Net quantity of electricity generated and delivered to the grid by power unit *m* in year *y* (MWh) |
| $EF_{EL,m,y}$ | = | $CO_2$ emission factor of power unit *m* in year *y* (t $CO_2$/MWh) |
| *m* | = | Power units included in the build margin |
| *y* | = | Most recent historical year for which electricity generation data is available |

## Determining the Combined Margin (CM) Emission Factor & Calculation Equations

The calculation of the combined margin (CM) emission factor ($EF_{grid,CM,y}$) is based on one of the following methods as shown in Figure 8 and Figure 9:

a) Weighted average CM or
b) Simplified CM

**Figure 8: Flow chart to calculate CM**

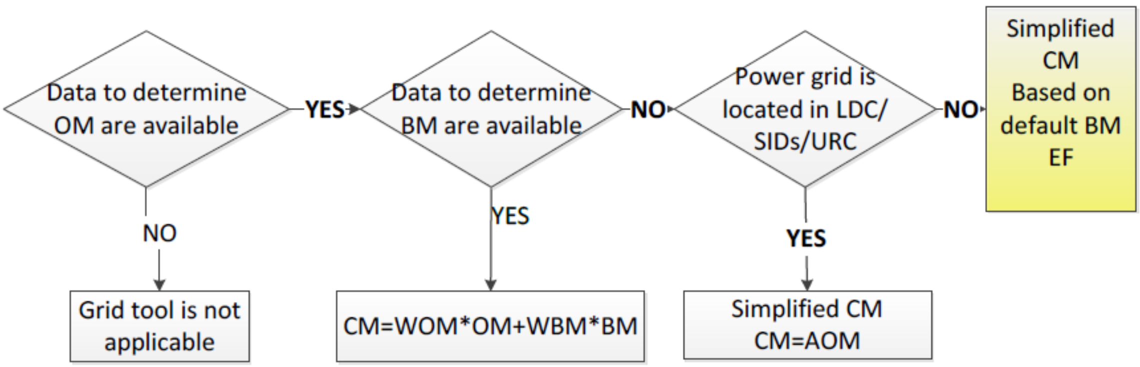


**Figure 9: Equation to calculate Combined Margin (CM)**

$$EF_{grid,CM,y} = EF_{grid,OM,y} \times w_{OM} + EF_{grid,BM,y} \times w_{BM}$$

Where:

| | | |
|---|---|---|
| $EF_{grid,BM,y}$ | = | Build margin $CO_2$ emission factor in year *y* (t $CO_2$/MWh) |
| $EF_{grid,OM,y}$ | = | Operating margin $CO_2$ emission factor in year *y* (t $CO_2$/MWh) |
| $w_{OM}$ | = | Weighting of operating margin emissions factor (per cent) |
| $w_{BM}$ | = | Weighting of build margin emissions factor (per cent) |

All projects (except solar and wind power generation): $W_{OM}$ = 0.5 and $W_{BM}$ = 0.5. Alternative weight can be proposed as long as $W_{OM}$ + $W_{BM}$ = 1 as guided in methodological tool.

# 3. POWER GRID SYSTEM IN MALAYSIA

The Malaysian National Grid is the high-voltage electric transmission network owner in Peninsular Malaysia. It is operated and owned by Tenaga Nasional Berhad (TNB), specifically by TNB's Transmission Division. The East Malaysia grid system in Sabah and Sarawak is operated by Sabah Electricity Sdn. Bhd. (SESB) and Sarawak Energy Berhad (SEB) respectively.

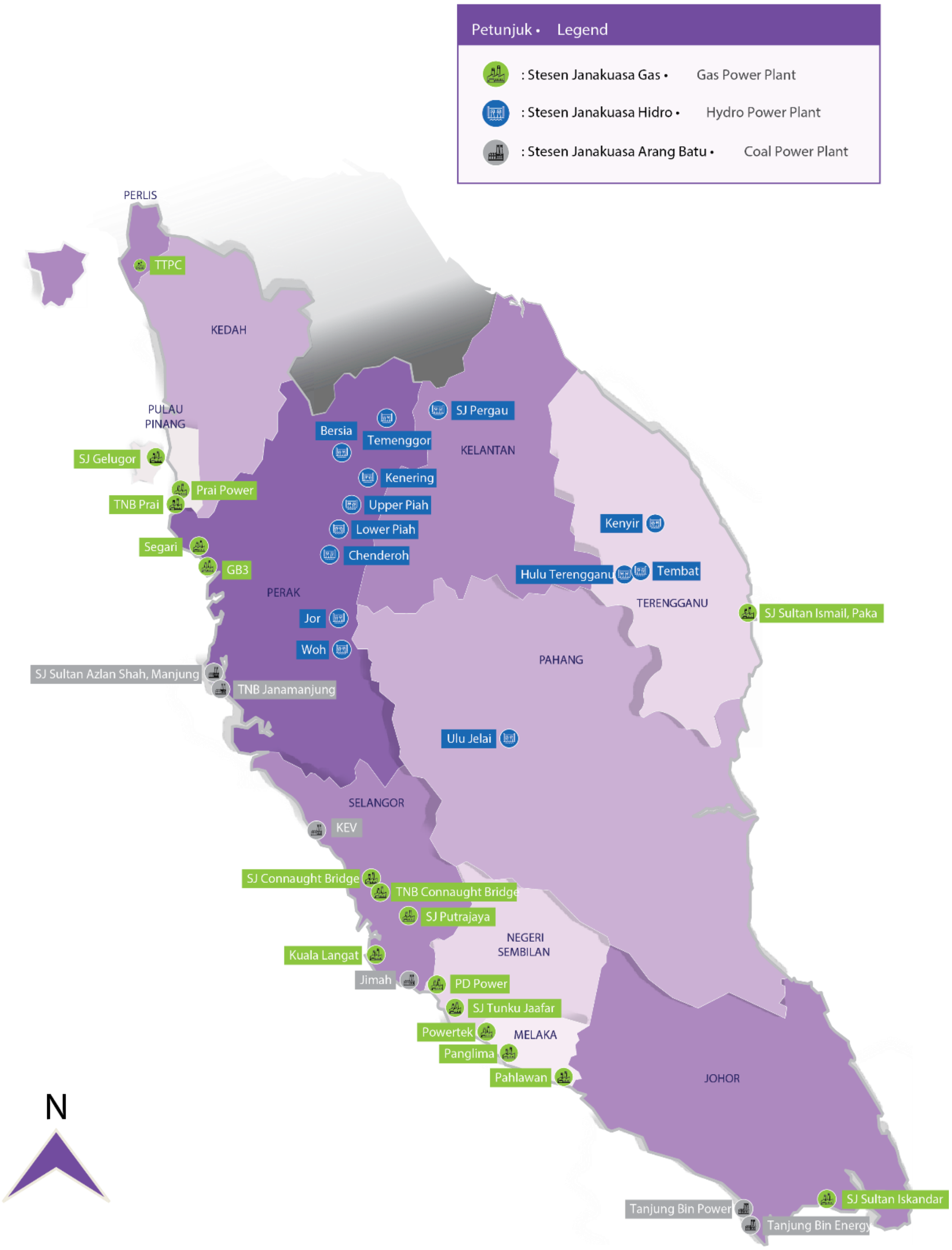
The grid system in Peninsular Malaysia connects electricity generation stations owned by TNB and Independent Power Producers (IPPs) to energy consumers. A small number of consumers, mainly steel mills and shopping malls also take power directly from the National Grid.

As a regulator, Suruhanjaya Tenaga (Energy Commission) was established in 2001 by the Malaysian government to advance the potential of the energy supply industry. It warrants the dependable, reliable, safe and cost-effective supply of electricity, especially to Peninsular Malaysia and Sabah.

Figure 10 below illustrates the location of power plants and the grid system in Peninsular Malaysia. TNB is a net exporter of electricity to Thailand. Port Dickson Power and Powertek are the existing plants that have been operationally extended to supply 436MW and 434MW power respectively to the grid until 2019. The extension of Sultan Ismail Power Plant, Paka of 257MW has also been approved until the end of 2019.

TNB Janamanjung Unit 5 is the latest coal-fired power unit that has started its operation. The power unit with capacity of 1,000MW was commissioned in the third quarter of 2017 and utilizes ultra-supercritical technology.

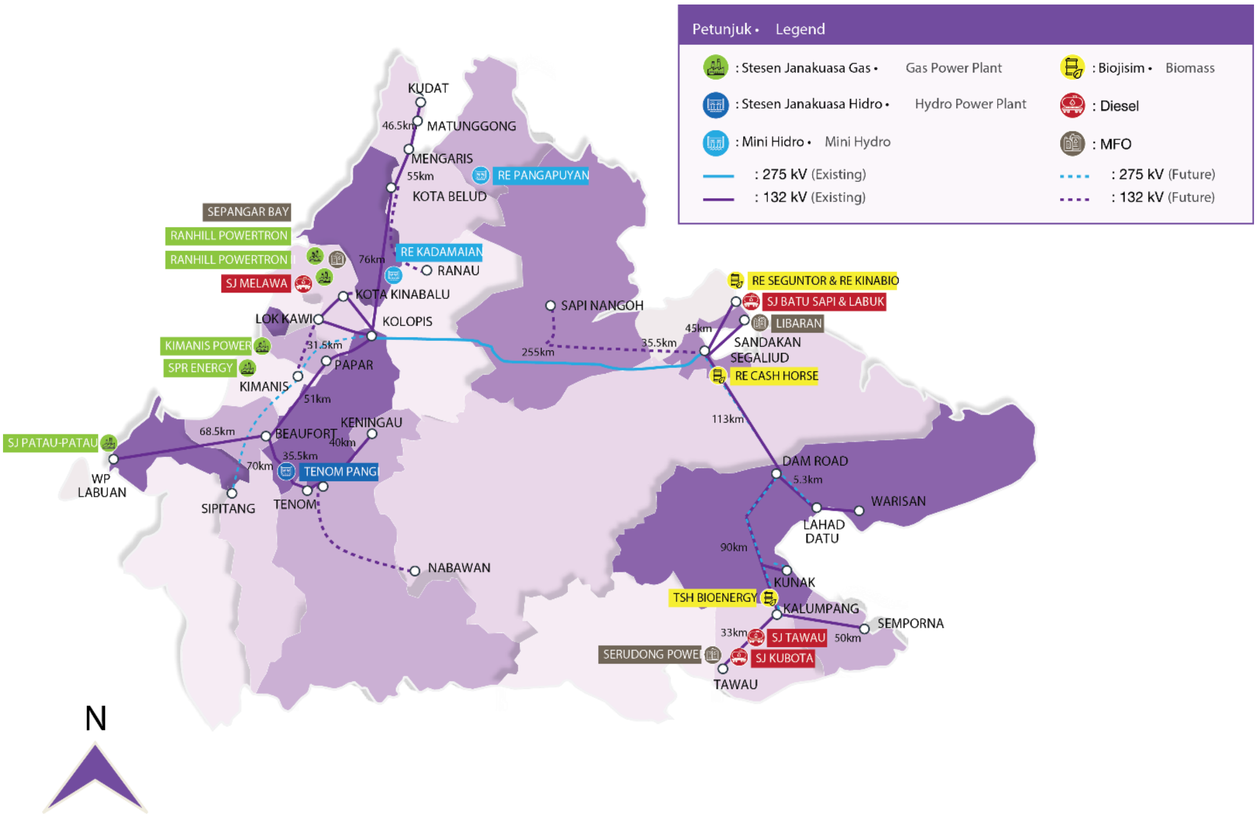
**Figure 10: Location of power plants in Peninsular Malaysia**




*Source: Energy Commission of Malaysia*

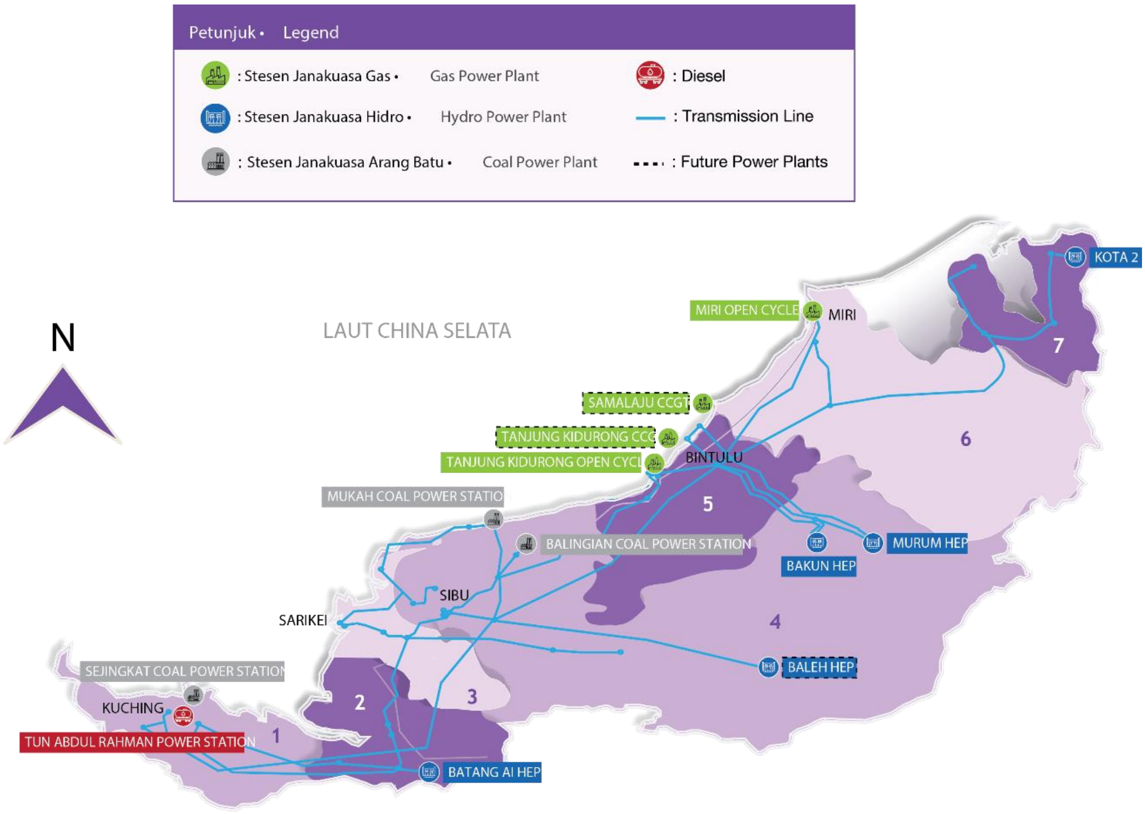
In Sabah and Sarawak, electricity is generated by fossil fuels (oil and coal) and hydroelectric. The power systems in Sabah and Sarawak are shown in Figure 11 and Figure 12 below. The demand for electricity is increasing in these two regions and encouraging usage of renewable energy sources such as biomass and biogas.

## Figure 11: Location of power plants in Sabah




*Source: Energy Commission of Malaysia*

**Figure 12: Location of power plants in Sarawak**




*Source: Energy Commission of Malaysia*

## 3.1 Power Plant Technology in Malaysia

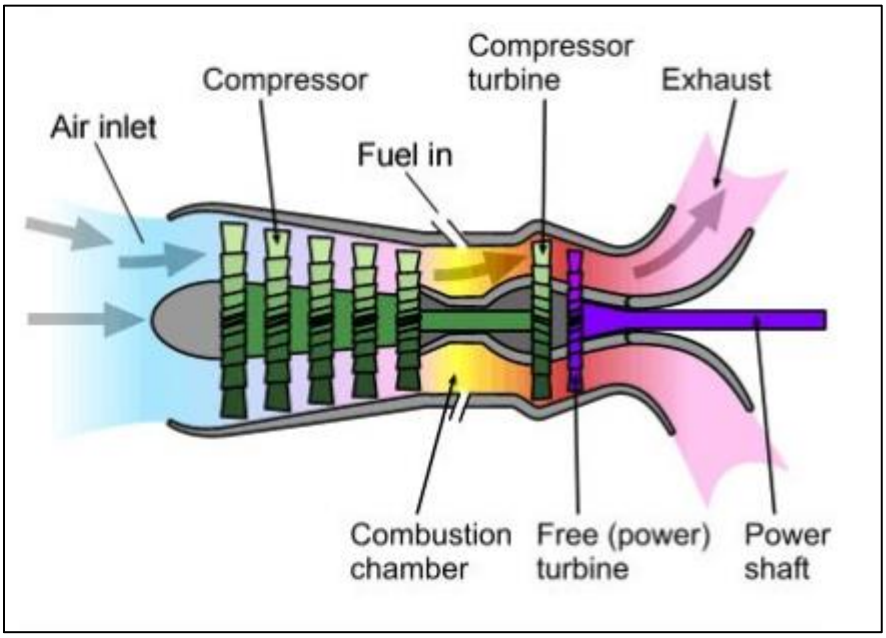
Types of power generation technologies used to generate electricity in Malaysia include:

i) Open Cycle Gas Turbine (OCGT)
ii) Combined Cycle Gas Turbine (CCGT)
iii) Coal-Fired Power Plant
iv) Conventional Thermal
v) Hydroelectric Power Plant
vi) Renewable Energy

### 3.1.1 Open Cycle Gas Turbine

Open-Cycle Gas Turbine (OCGT) Power Plant is a power plant which uses liquid fuel to turn a turbine that produces electricity. In terms of operation, this plant works on an open cycle where the input is supplied to each cycle and after combustion and expansion, it will be discharged to the atmosphere. Part load efficiency for OCGT is less compared to CCGT.

**Figure 13: Open Cycle Gas Turbine**




Source: www.ipieca.org

How OCGT generates electricity:

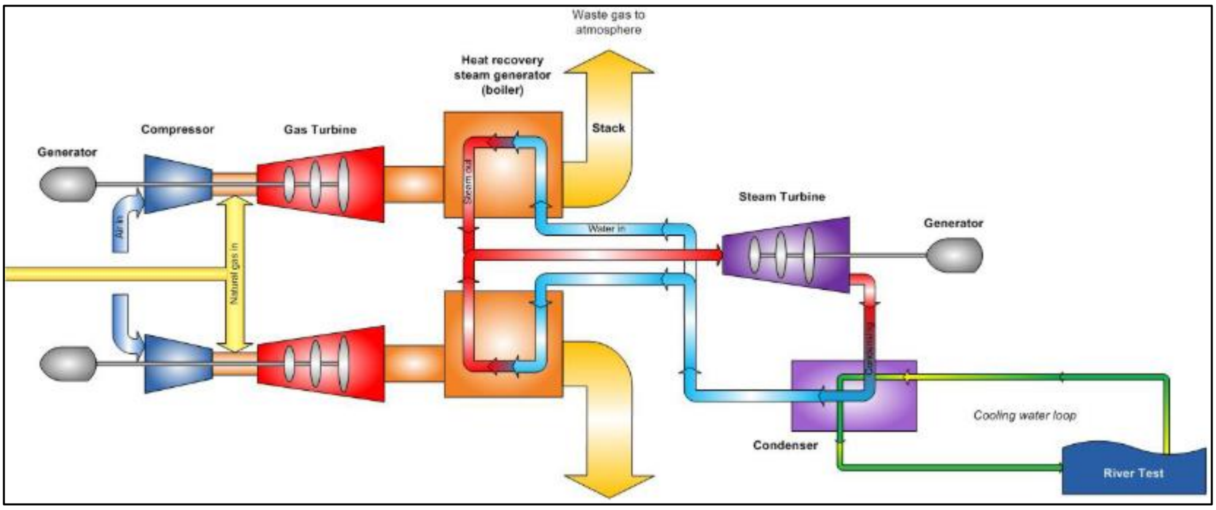
1. A compressed air and fuel are mixed and burned at the combustion chamber where this process causes it to expand **(emissions occur at this stage).**
2. The expansion will create a pressure where it will be passed through the blades of gas turbine that turn the shaft that is attached to the rotor of the generator.
3. The rotor turns inside the stator and electricity is generated.

### 3.1.2 Combined Cycle Gas Turbine

Combined-Cycle Gas Turbine Power Plant is a power plant which uses both a gas and steam turbine to produce electricity from the same fuel type simultaneously.

Usually, the CCGT power plant can produce up to 50 percent more electricity than a traditional simple-cycle plant.

**Figure 14: Combined Cycle Gas Turbine**




Source: Marchwood Power

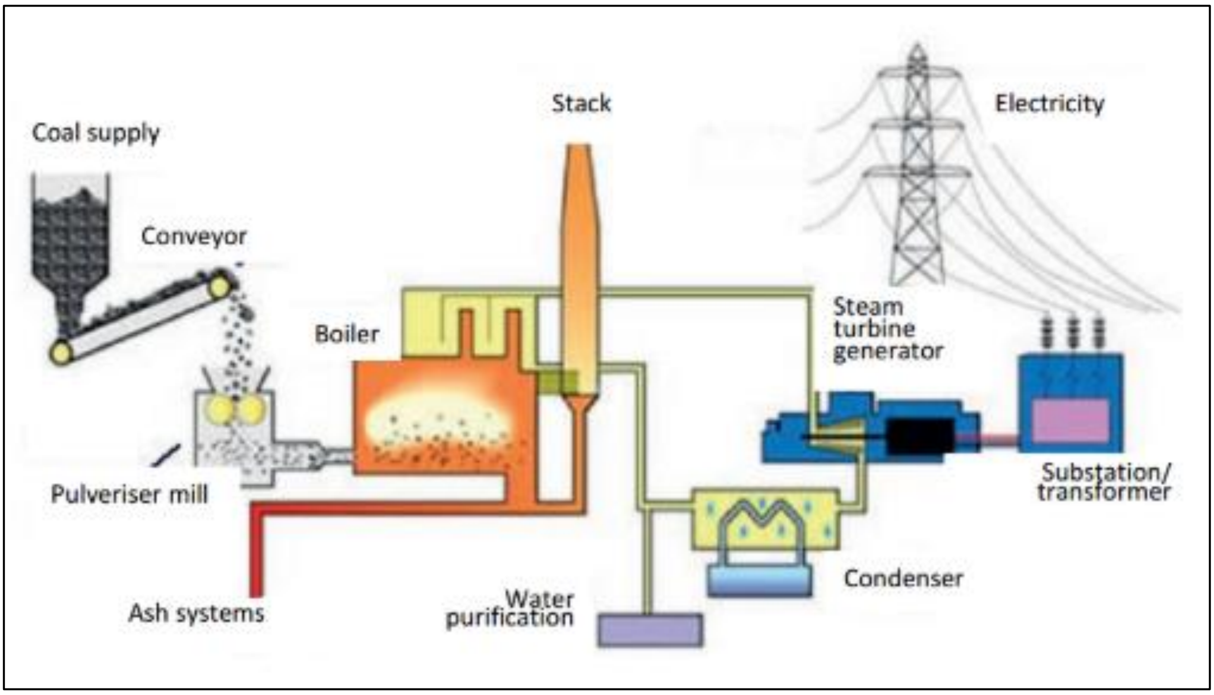
How CCGT generates electricity:

1. A compressed air and natural gas are mixed and burned where this process causes it to expand **(emissions occur at this stage).**
2. The expansion will create a pressure where it will spin the blades of gas turbine and generate electricity.
3. The heat from the gas turbine will then pass through the heat recovery generator system and generate steam.
4. The steam will then be channeling through the thermal turbines to generate electricity.
5. The steam will then be passed to the condenser to be condensed as a feed water for the recovery generator system.
6. The hot gas from the thermal turbines will then be discharged to the atmosphere.

### 3.1.3 Coal-Fired Power Plant

According to the World Coal Association, coal-fired power plant currently contributes 37% of global electricity. Coal-fired Power Plant is a power plant which uses the combustion of coal to produce electricity. These plants require plenty of water to be circulated in the cycle namely the Rankine Cycle, thus the plants need to be located near a body of water.

**Figure 15: Coal-fired Power Plant**




Source: World Coal Association

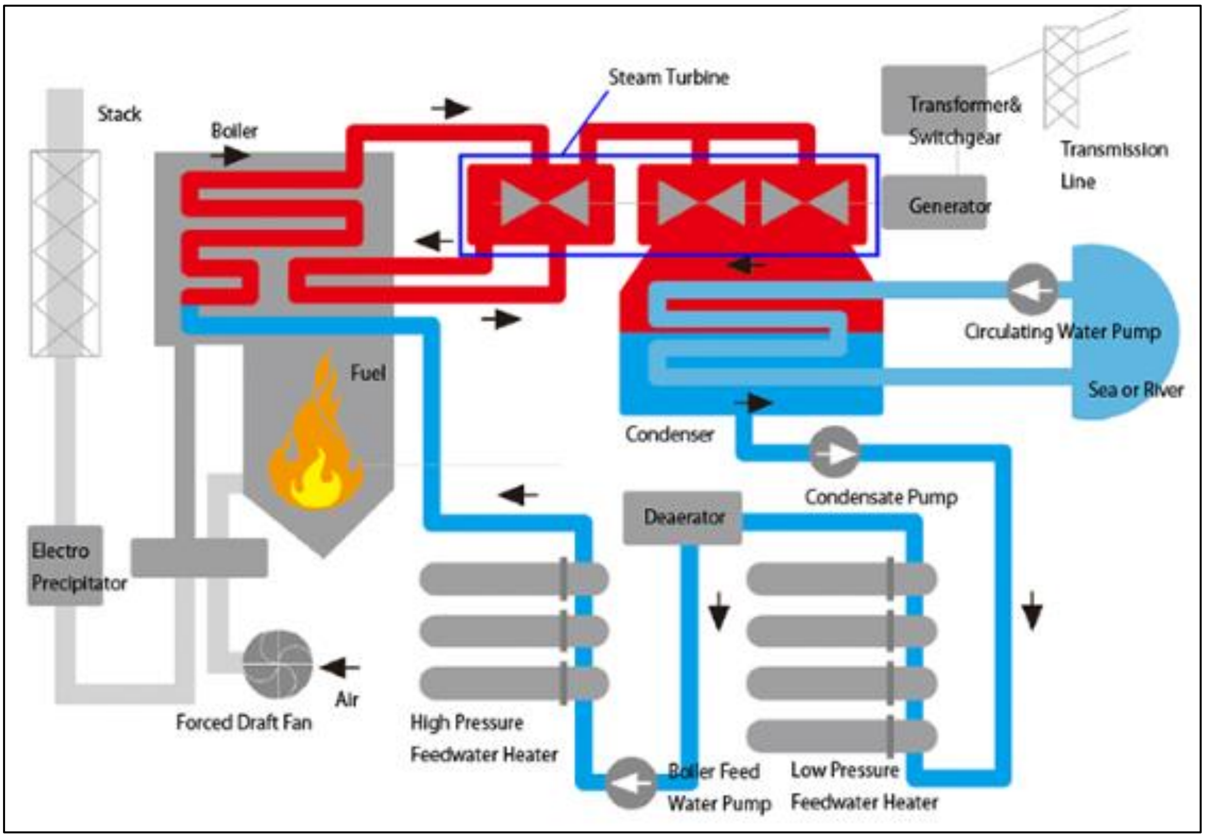
How Coal-fired power plants generate electricity:

1. A coal is burned in a boiler to produce steam **(emissions occur at this stage).**
2. The steam will flow into the steam turbine generator where it will spin the blades of the turbine and generate electricity.
3. The steam from the turbine is then cooled and will be condensed back into water through the condenser.
4. The water will be returned to the boiler to start the process over.

### 3.1.4 Conventional Thermal Power Plant

Conventional Thermal Power Plant is a power plant which uses heat energy to turn a steam turbine generator to produce electricity.

**Figure 16: Conventional Thermal Power Plant**




Source: www.toshiba-energy.com

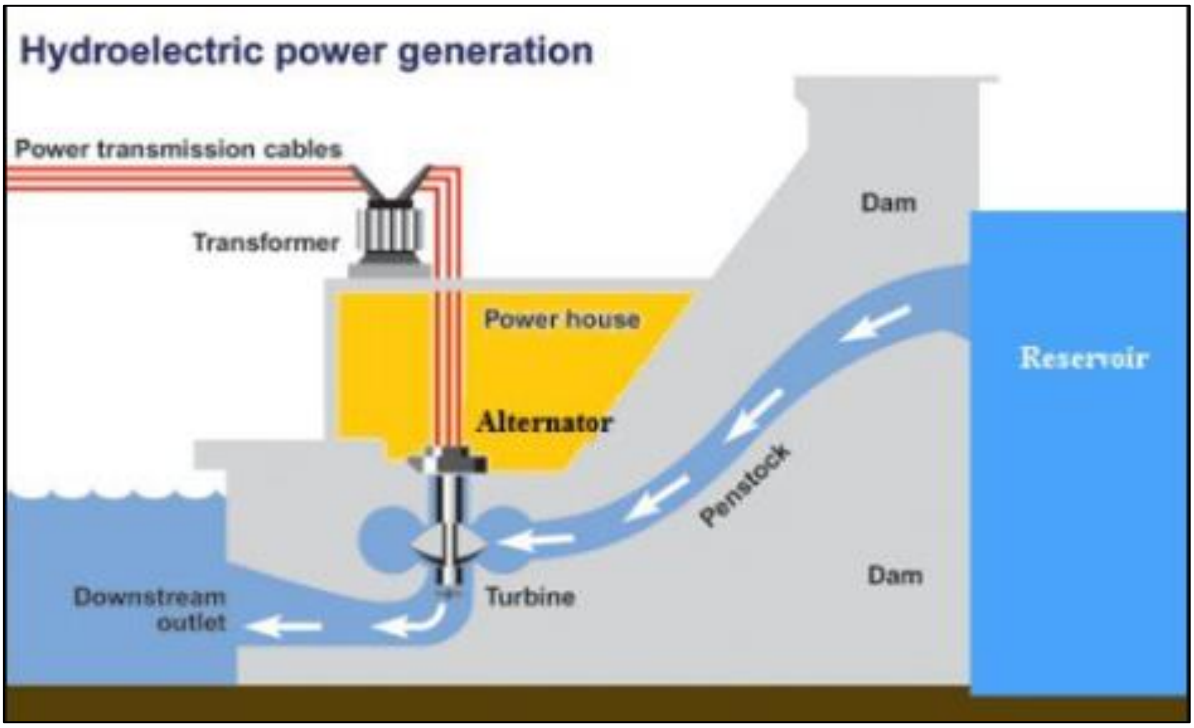
How Conventional Thermal Power Plants generate electricity:

1. A water is heated in a boiler to produce steam by burning the fuel **(emissions occur at this stage).**
2. The steam will flow into the steam turbine generator where it will spin the blades of turbine and drive the electric generator to generate electricity.
3. The steam from the steam turbine generator is then cooled and will be condensed back into water through the condenser for reusing.
4. The water will be returned to the boiler to start the process over.

### 3.1.5 Hydroelectric Power Plant

Hydroelectric Power Plant captures the energy of failing water to generate electricity. For this power plant, the turbine will convert the kinetic energy of falling water into mechanical energy. After that, a generator will convert the mechanical energy into electrical energy.

**Figure 17: Hydroelectric Power Plant**




Source: www.theelectricalportal.com

### 3.1.6 Renewable Energy

Renewable energy is electricity that is generated or produced from renewable resources which are naturally replenished. The major types of renewable energy sources are:

i. Biomass
ii. Biogas
iii. Geothermal
iv. Hydropower
v. Wind
vi. Solar

Renewable energy sources can be used to produce electricity with fewer environmental impacts. It is possible to make electricity from renewable energy sources without producing carbon dioxide ($CO_2$), the leading cause of global climate change.

**Figure 18: Renewable Energy**

Source: World of Renewables

# 4. DATA COLLECTION

GreenTech Malaysia has prepared CDM Electricity Baseline for 2017 based on data received from the following relevant data providers:

1. Suruhanjaya Tenaga (Energy Commission) for Peninsular Malaysia grid data and Renewable Energy (Non-Feed-in Tariff) projects.
2. Sabah Electricity Sdn Bhd (SESB) for Sabah grid data and Net Calorific Value (NCV) for Medium Fuel Oil (MFO).
3. Sarawak Energy Berhad (SEB) for Sarawak grid data and Net Calorific Value (NCV).
4. Single Buyer for Load Duration Curve Graph for Peninsular Malaysia, fuel density and Net Calorific Value (NCV).
5. Sustainable Energy Development Authority (SEDA) for Renewable Energy (Feed-in Tariff) projects.
6. MESTECC for Clean Development Mechanism (CDM) projects in Malaysia.

List of data required from the data providers are as follows:

i. Type of power plant
ii. Capacity
iii. Number of Power Unit at each plant
iv. Net generation
v. Fuel consumption
vi. Net plant efficiency
vii. Year of commissioning (where necessary)

# 5. DATA ANALYSIS AND EMISSION FACTOR

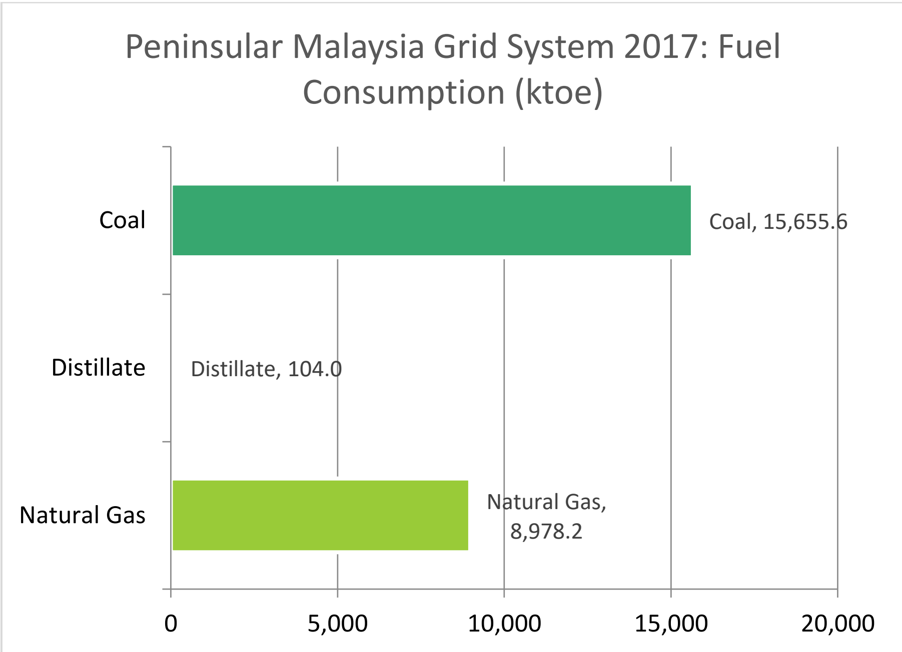
Having thoroughly analysed the calculation methodology of Peninsular Malaysia, Sabah and Sarawak, the required input data for the calculation of the annual grid electricity emission factors will be presented hereinafter. The data was obtained directly from the grid operators and regulator according to regions based on requirements in the CDM Methodological Tool. The publicly available data was used for verification on the accuracy of the data.

## 5.1 Input Data for Calculation

### 5.1.1 Fuel Consumption by Power Plants

Figure 19 and Table 2 show the fuel consumption (ktoe) of the Peninsular Malaysia grid system in 2017. Total fuel consumption in 2017 was 24,734 ktoe with the major fuel consumption from coal plants at 15,656 ktoe or 63%. This was followed by natural gas plants at 8,978 ktoe or 36% and minimum amount of distillate is used for plant operation at 104 ktoe.

**Figure 19: Fuel consumption for Peninsular Malaysia for year 2017**



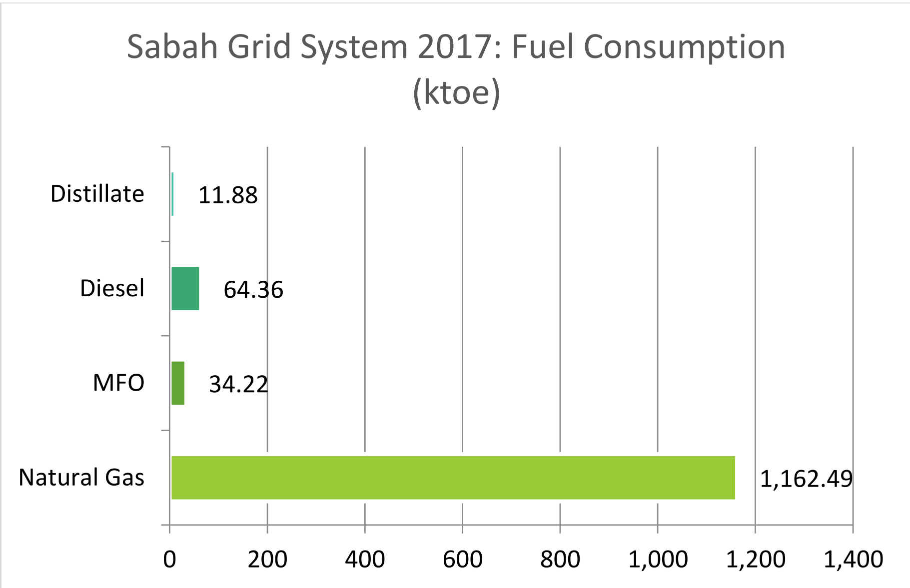

The consumption of natural gas in Peninsular Malaysia reduced by 20% and distillate by 84%, while usage of coal increased by 35% in 2017 compared to 2013.

**Table 2: Fuel consumption by fuel type (2013 - 2017) in Peninsular Malaysia**

| Fuel type | Fuel Consumption (ktoe) | | | | | Fuel usage in 2017 compared to 2013 |
|---|---|---|---|---|---|---|
| | 2013 | 2014 | 2015 | 2016 | 2017 | |
| Natural Gas | 11,268 | 12,051 | 9,721 | 9,494 | 8,978 | -20% |
| Distillate | 661 | 310 | 15 | 154 | 104 | -84% |
| Coal | 11,621 | 11,425 | 11,657 | 14,119 | 15,656 | 35% |
| Total | 23,550 | 23,786 | 21,393 | 23,767 | 24,738 | |

Figure 20 and Table 3 show the total fuel consumption for Sabah grid system in year 2017. Natural gas was the major source of fuel consumption at 1,162 ktoe (91%), followed by diesel at 64 ktoe (5%), MFO at 34 ktoe (3%) and distillate at 12 ktoe (1%).

**Figure 20: Fuel consumption for Sabah for year 2017**



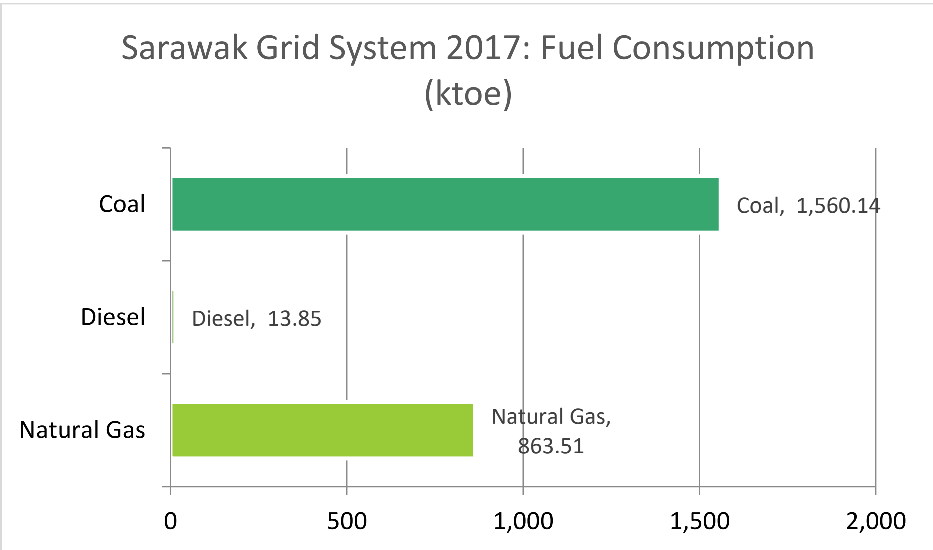

Sabah power plants increased the usage of natural gas, medium fuel oil (MFO) and distillate by 56%, 48% and 71% respectively, while the usage of diesel reduced by 74% compared to 2013.

**Table 3: Fuel Consumption by fuel type (2013 - 2017) in Sabah**

| Fuel type | Fuel Consumption (ktoe) | | | | | Fuel usage in 2017 compared to 2013 |
|---|---|---|---|---|---|---|
| | 2013 | 2014 | 2015 | 2016 | 2017 | |
| Natural Gas | 743 | 945 | 1,097 | 1,193 | 1,162 | 56% |
| MFO | 23 | 10 | 47 | 47 | 34 | 48% |
| Diesel | 246 | 231 | 138 | 71 | 64 | -74% |
| Distillate | 7 | 12 | - | 11 | 12 | 71% |
| Total | 1,019 | 1,198 | 1,282 | 1,322 | 1,272 | |

Figure 21 and Table 4 show the fuel consumption (ktoe) of the Sarawak grid system in 2017. The total fuel consumption was 2,420 ktoe, mainly from coal at 1,560 ktoe or 64%, followed by natural gas at 864 ktoe or 35% and diesel at 14 ktoe or 1%.

**Figure 21: Fuel consumption for Sarawak for year 2017**




In Sarawak, the power plants used less fuel in 2017 compared to 2013. The natural gas and coal usage decrease to 2.3% and 16.6% respectively and there is usage of diesel in 2016 and 2017 in Sarawak.

**Table 4: Fuel consumption by fuel type (2013 - 2017) in Sarawak**

| Fuel type | Fuel Consumption (ktoe) | | | | | Fuel usage in 2017 compared to 2013 |
|---|---|---|---|---|---|---|
| | 2013 | 2014 | 2015 | 2016 | 2017 | |
| Natural Gas | 884 | 800 | 719 | 1,747 | 864 | -2.3% |
| Distillate | 2.5 | 10.0 | 7.9 | 9.9 | 0.0 | -100% |
| Coal | 1,870 | 2,100 | 2,170 | 2,991 | 1,560 | -16.6% |
| Diesel | 0 | 0 | 0 | 22 | 14 | 100% |
| Total | 2,756.5 | 2,910 | 2,896.9 | 4,769.9 | 2,438 | |

## 5.1.2 Electricity Generated to the Grid & Plant Efficiency by Technology

Figure 22 shows the breakdown of electricity generation (GWh) in Peninsular Malaysia in 2017. Electricity sold from coal plants was the highest at 54%, followed by natural gas plants at 39% and hydro plants at 6%. Renewable energy which consists of mini-hydro, Feed in Tariff and Non-Feed in tariff projects contributed to 1% from the total generation.

**Figure 22: Peninsular Malaysia electricity generation (2017)**

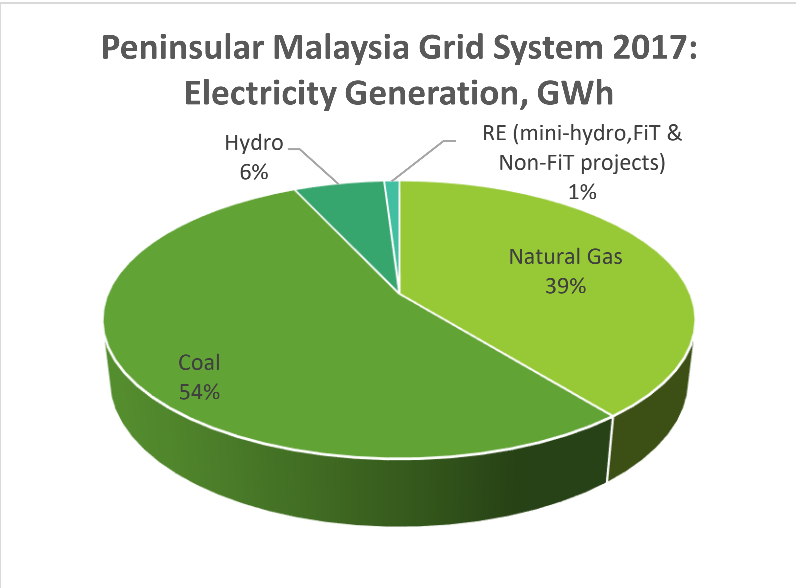



Table 5 shows the average plant efficiency of the various types of power plants in Peninsular Malaysia in 2017. From the fossil fuel power plants, CCGT (natural gas) plants were the most efficient at 43%, followed by conventional power plant at 35%. Total grid net generation from thermal power plants and hydro power plants & renewable energy projects was 111,698 GWh and 8,280 GWh respectively.

**Table 5: Peninsular Malaysia plant efficiency by technology**

| Peninsular Malaysia | | |
|---|---|---|
| Electricity Generation System | Grid Net Generation (GWh) | Plant Efficiency |
| Thermal Power Plants (Non-LCMR) | | |
| CCGT (Natural Gas) | 46,029.73 | 43.0% |
| OCGT (Natural Gas / Distillate) | 624.92 | 26.0% |
| Coal Fired | 64,637.93 | 34.8% |
| Conventional (Natural Gas / Distillate) | 405.29 | 35.0% |
| Total Non-LCMR | **111,697.87** | |
| Hydro Power Plants / Renewable Energy (LCMR) | | |
| Hydro | 7,088.14 | |
| RE (FiT) | 1,191.34 | |
| RE (Non-FiT) | | |
| Total LCMR | **8,279.48** | |
| Total (Non-LCMR + LCMR) | **119,977.35** | |

Figure 23 shows the breakdown of the electricity generation (GWh) in the Sabah Grid System in 2017. Most of electricity sold was generated from natural gas plants at 83%, followed by renewable energy at 7% and hydro power plants at 5%.

**Figure 23: Sabah electricity generation (2017)**

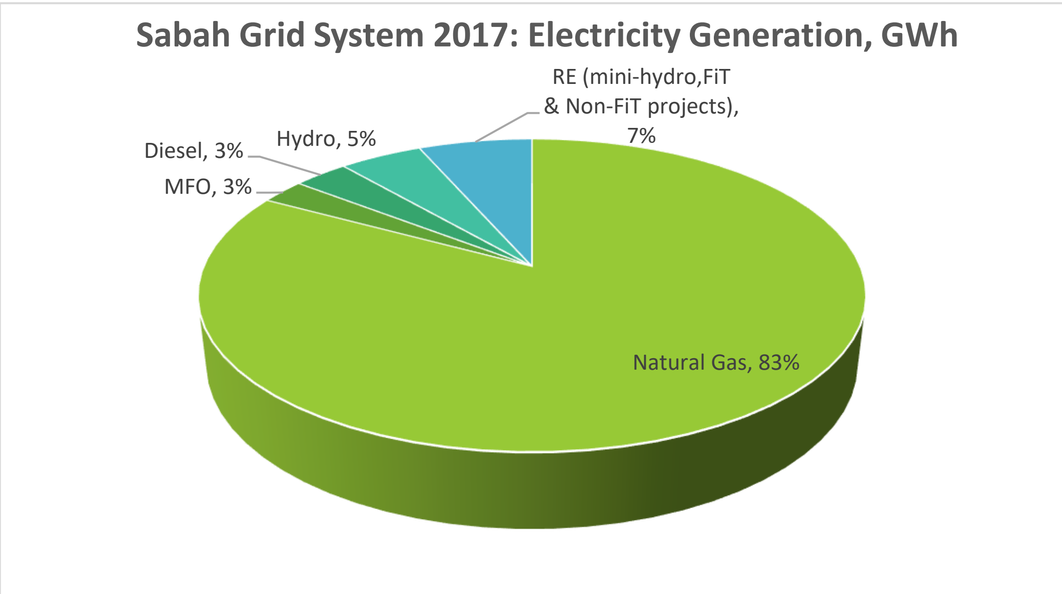



Table 6 shows the efficiency of power plants types in Sabah in 2017. The most efficient fossil fuel power plant was diesel generation (MFO & Diesel) plants at 36%, followed by CCGT (Natural Gas) power plants at 33%. Total grid net generation from thermal power plants was 5,675 GWh, while total grid net generation from hydro power plants and renewable energy projects was 728 GWh.

**Table 6: Sabah plant efficiency by technology**

| Sabah | | |
|---|---|---|
| Electricity Generation System | Grid Net Generation (GWh) | Plant Efficiency |
| Thermal Power Plants (Non-LCMR) | | |
| CCGT (Natural Gas) | 5,307.55 | 32.7% |
| OCGT (Diesel) | 186.52 | 28.1% |
| DG (MFO & Diesel) | 180.64 | 35.9% |
| Total Non-LCMR | **5,674.71** | |
| Hydro Power Plants / Renewable Energy (LCMR) | | |
| Hydro | 306.91 | |
| RE (FiT) | 404.46 | |
| RE (Non-FiT) | 16.27 | |
| Total LCMR | **727.64** | |
| Total (Non-LCMR+LCMR) | **6,402.35** | |

Figure 24 shows the breakdown of the electricity generation (GWh) in the Sarawak Grid System in 2017. The majority of electricity sold came from hydro plants at 77%, followed by natural gas plants at 12% and coal plants at 11%.

**Figure 24: Sarawak electricity generation (2017)**

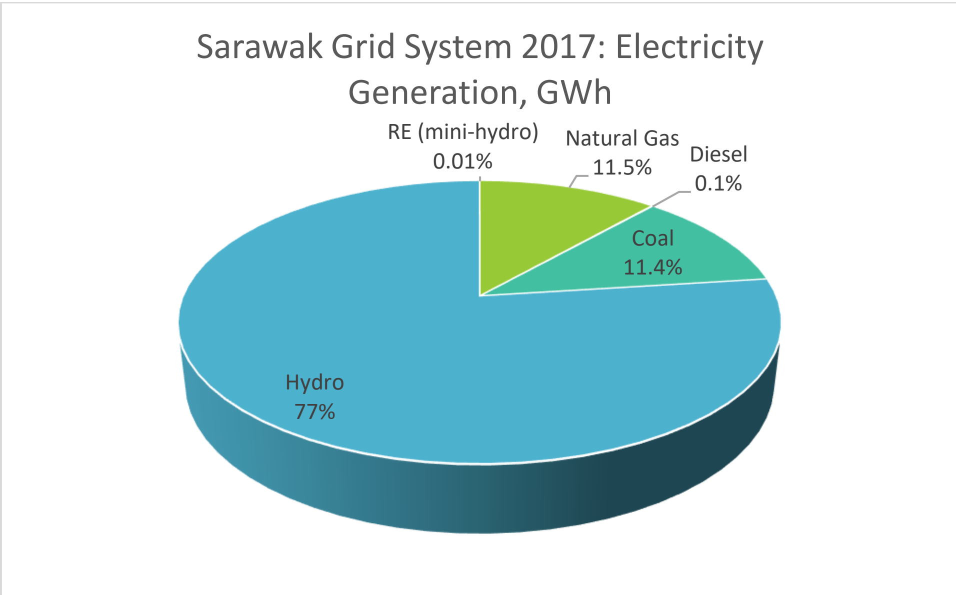



Table 7 shows the efficiency of power plants in Sarawak in 2017. Coal fired plants had the highest efficiency at 30.9%, followed by diesel generation (DG) plants at 30.5% and OCGT at 27% efficiency respectively. Total grid net generation from hydro power plants and renewable energy projects at 19,241 GWh exceeded that from thermal power plants at 5,737 GWh.

**Table 7: Sarawak plant efficiency by technology**

| Sarawak | | |
|---|---|---|
| Electricity Generation System | Grid Net Generation (GWh) | Plant Efficiency |
| Thermal Power Plants (Non-LCMR) | | |
| OCGT/CCGT (Natural Gas/ Diesel) | 2,869.07 | 27.0% |
| DG (Diesel/Natural Gas) | 16.18 | 30.5% |
| Coal Fired | 2,852.20 | 30.9% |
| Total Non-LCMR | **5,737.46** | |
| Hydro Power Plants / Renewable Energy (LCMR) | | |
| Hydro | 19,237.98 | |
| Mini hydro | 2.62 | |
| Total LCMR | **19,240.60** | |
| Total (Non-LCMR+LCMR) | **24,978.06** | |

## 5.2 Data Analysis

### 5.2.1 $CO_2$ co-efficient Emission Factor

The specific data and information from power plant operators influences the accuracy of emission factors. For this study, the Net Calorific Value (NCV) used were based on specific NCV from power plants. Hence, it helps in improving the accuracy of the $CO_2$ Emission Co-efficient as well as the findings of the emission factor for all regions. The co-efficient used in the calculation is listed in the Table 8.

**Table 8: $CO_2$ co-efficient used in the calculation**

| Fuel Types | Calorific Value (GJ/ton) | Oxidation Factor (%) | Emission Factor (tCO2/GJ) | CO2 Emission Coefficient (tCO2/t fuel) | Emission Factor (tCO2/TJ) | CO2 Emission Coefficient (tCO2/TJ) |
|---|---|---|---|---|---|---|
| Power Plant (Coal) | 21.76 | 100% | 0.096 | 2.09 | 96.10 | 96.10 |
| Power Plant A Peninsular Malaysia (Coal) | 21.54 | 100% | 0.096 | 2.07 | 96.10 | 96.10 |
| Power Plant B Peninsular Malaysia (Coal) | 21.88 | 100% | 0.096 | 2.10 | 96.10 | 96.10 |
| Power Plant C Peninsular Malaysia (Coal) | 26.11 | 100% | 0.095 | 2.47 | 94.60 | 94.60 |
| Power Plant D Peninsular Malaysia (Coal) | 26.32 | 100% | 0.095 | 2.36 | 94.60 | 94.60 |
| | 22.43 | 100% | 0.096 | | 96.10 | 96.10 |
| | 26.09 | 100% | 0.095 | 2.36 | 94.60 | 94.60 |

| Fuel Types | Calorific Value (GJ/ton) | Oxidation Factor (%) | Emission Factor ($tCO_2/GJ$) | $CO_2$ Emission Coefficient ($tCO_2/t$ fuel) | Emission Factor ($tCO_2/TJ$) | $CO_2$ Emission Coefficient ($tCO_2/TJ$) |
|---|---|---|---|---|---|---|
| Power Plant E Peninsular Malaysia (Coal) | 22.05 | 100% | 0.096 | | 96.10 | 96.10 |
| Power Plant F Peninsular Malaysia (Coal) | 21.54 | 100% | 0.096 | 2.07 | 96.10 | 96.10 |
| Power Plant A Sarawak (Coal) | 18.35 | 100% | 0.096 | 1.76 | 96.10 | 96.10 |
| Power Plant B Sarawak (Coal) | 17.90 | 100% | 0.096 | 1.72 | 96.10 | 96.10 |
| Power Plant C Sarawak (Coal) | 15.08 | 100% | 0.093 | 1.40 | 92.80 | 92.80 |
| Power Plant A Sarawak (Diesel) | 41.30 | 100% | 0.073 | 3.00 | 72.60 | 72.60 |
| Power Plant B Sarawak (Diesel) | 40.90 | 100% | 0.073 | 2.97 | 72.60 | 72.60 |
| MFO/Oil | 40.35 | 100% | 0.077 | 3.12 | 77.40 | 77.40 |
| Natural Gas | - | 100% | 0.056 | 0.06 | 56.10 | 56.10 |
| Distillate | 45.00 | 100% | 0.075 | 3.37 | 74.80 | 74.80 |
| Diesel | 45.00 | 100% | 0.075 | 3.37 | 74.80 | 74.80 |

### 5.2.2 Operating Margin

Operating Margin Emission Factors have been estimated for all regions by using the Simple Operating Margin (OM). As explained in the methodology chapter, the Simple OM was selected based on electricity generation and load capacity as follows:

i. Peninsular Malaysia and Sabah – The electricity generation from Low Cost/Must Run (LCMR) power plants in these two regions are less than 50% and the three years average load capacity of LCMR is lower than Lowest Annual Load Supply (LASL).

ii. Sarawak – Even though hydro generation is more than 50% in year 2017, the three years' average load capacity for LCMR is still lower than Lowest Annual Load Supply (LASL).

Option A1 from Simple OM is used to derive the emission factors and the equations are as below.

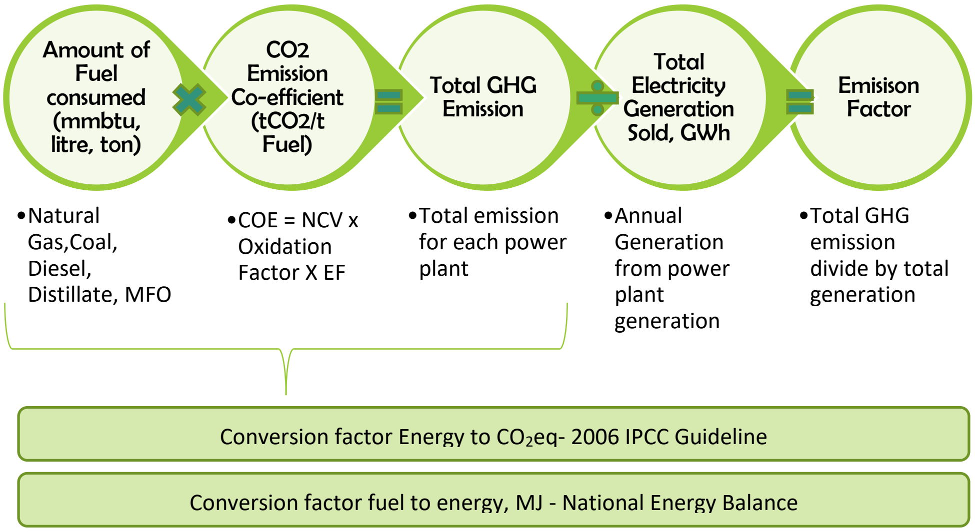



**Figure 25: $CO_2$ emissions from Operating Margin for Peninsular Malaysia, Sabah and Sarawak**

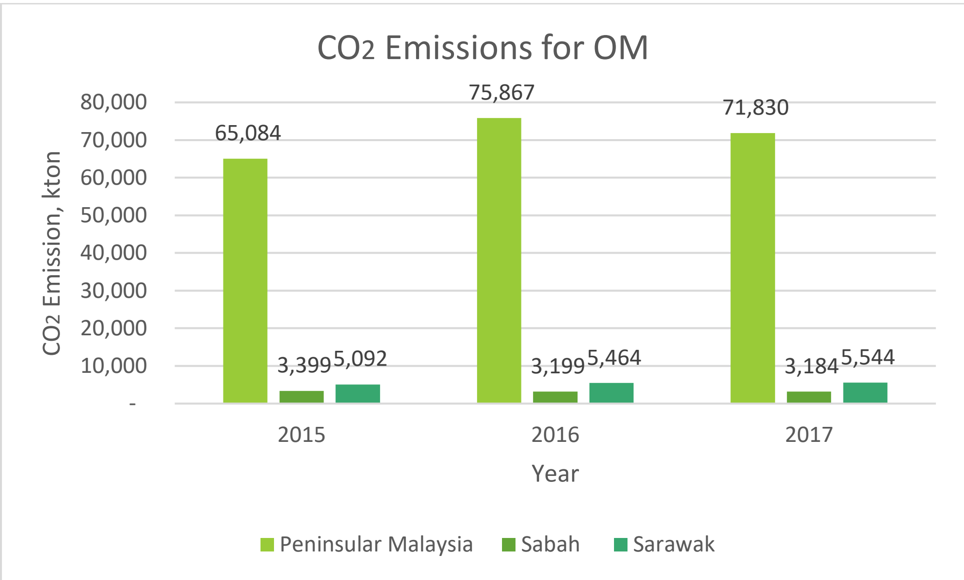



Table 9 shows the OM emission factor based on fuel consumption for Peninsular Malaysia is 0.645 $tCO_2/MWh$, while for Sabah and Sarawak are 0.564 $tCO_2/MWh$ and 0.967 $tCO_2/MWh$ respectively.

**Table 9: Operating Margin emission factor for 2017**

| Regions | Operating Margin (OM) | | | Average OM for 2017 |
|---|---|---|---|---|
| | 2015 | 2016 | 2017 | |
| | OM ($tCO_2/MWh$) | OM ($tCO_2/MWh$) | OM ($tCO_2/MWh$) | Average OM ($tCO_2/MWh$) |
| Peninsular Malaysia | 0.6285 | 0.6628 | 0.6431 | 0.6448 |
| Sabah | 0.5754 | 0.5545 | 0.5611 | 0.5637 |
| Sarawak | 0.9568 | 0.9769 | 0.9664 | 0.9667 |

### 5.2.3 Build Margin

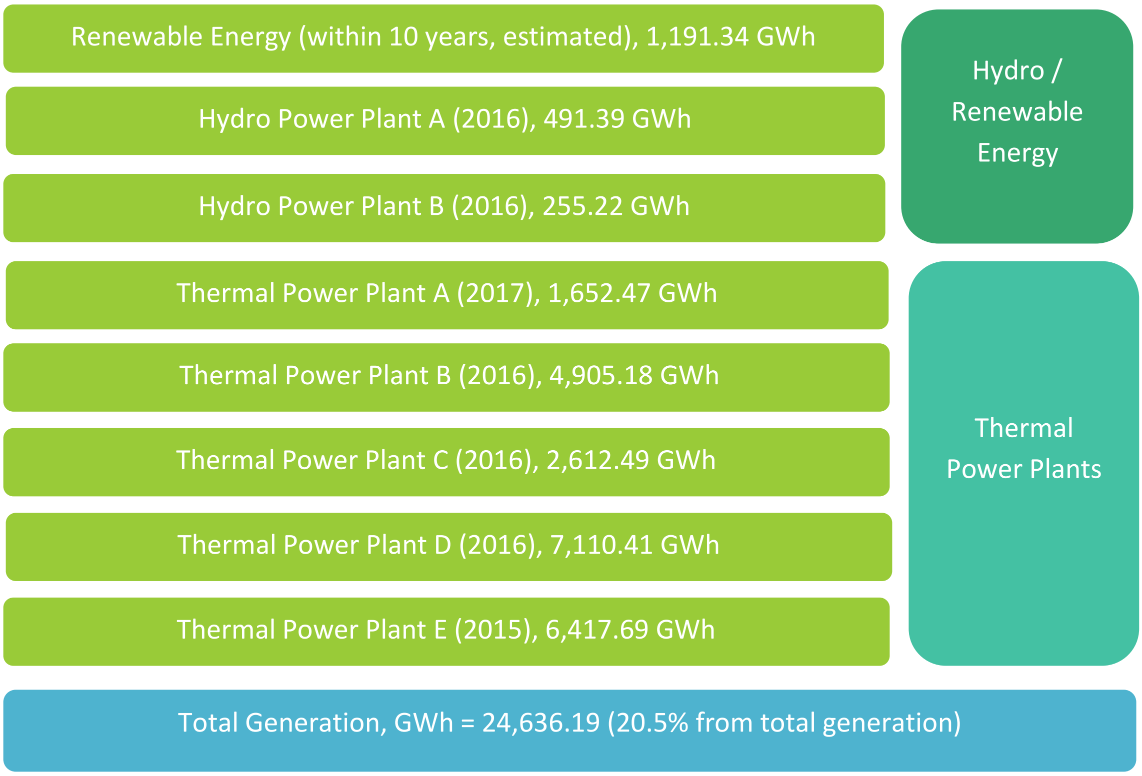
For Build Margin (BM), the emission factor was calculated based on two sets of listed power plants. The higher generation set was selected to calculate the Build Margin among the two listed as follows: -

i. Set of 5 most recent power plants/units ($SET_{5\ units}$)
ii. Set of recent power plants/units with generation of more than 20% of total generation ($SET_{>20\%\ units}$)
iii. The total generation for $SET_{>20\%\ units}$ higher than total generation from $SET_{5\ units}$ for Peninsular Malaysia and Sabah. While the total generation for $SET_{5\ units}$ higher than total generation from $SET_{>20\%\ units}$ for Sarawak. The power plant which was older than 10 years in Sarawak has been replaced with CDM project.

The power plants/units listed under $SET_{>20\%\ units}$ for Peninsular Malaysia and Sabah are shown in Figures 26 and 27 below.

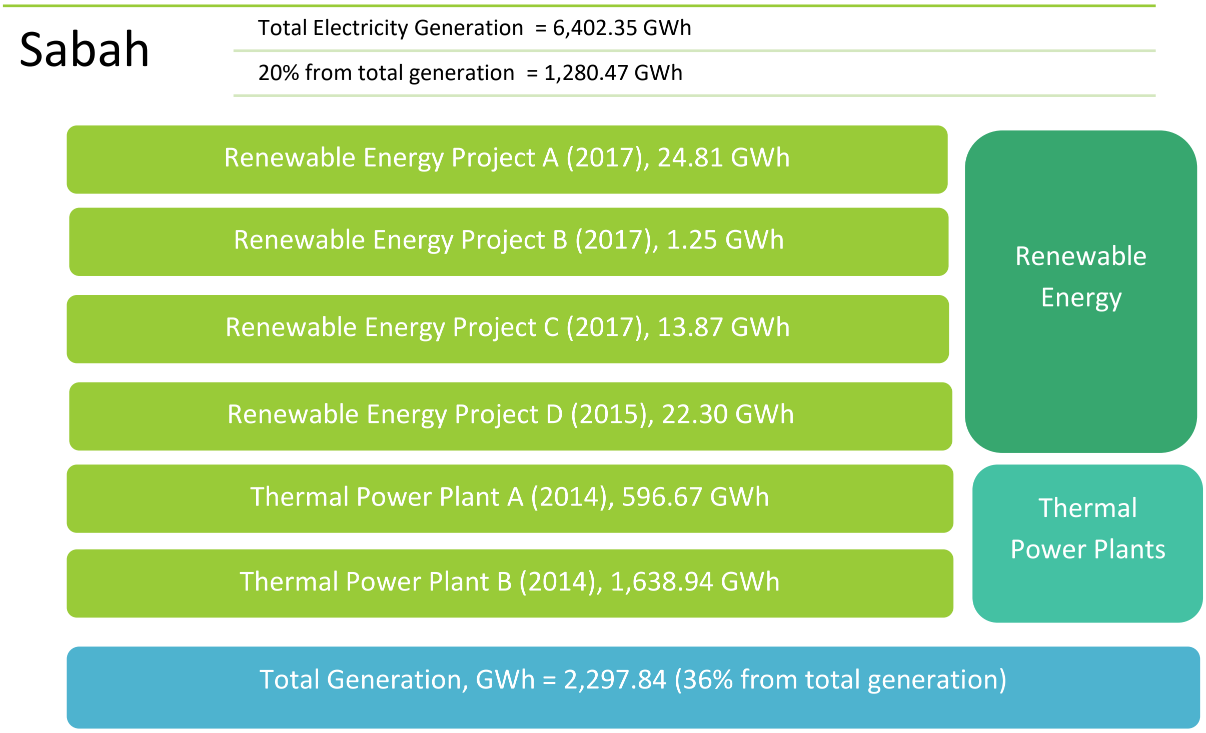
**Figure 26: Set of recent plants with generation of more than 20% of total generation in Peninsular Malaysia**

| | |
|---|---|
| Peninsular Malaysia | Total Electricity Generation = 119,977.35 GWh |
| | 20% from total generation = 23,995.47 GWh |




For Peninsular Malaysia, the total generation of SET $_{>20\%\ units}$ which consists of five thermal power plants and three hydro power plants / renewable energy projects amounted to 24,636 GWh. This amount is 20% of total generation of 119,977.35 GWh.

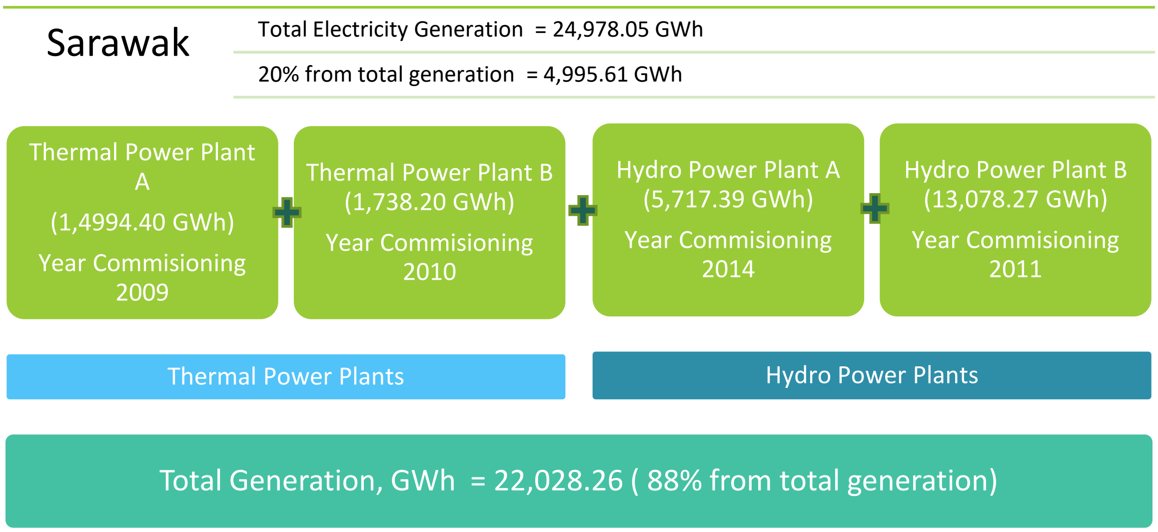
**Figure 27: Set of recent plants with generation of more than 20% of total generation in Sabah**




In Sabah, the most recent built power plants are renewable energy plants under Feed-in Tariff (FiT) Scheme which were mostly built in 2017. Among SET $_{>20\% \text{ units}}$, it consists of four renewable energy projects and two thermal power plants. The total generation for 2017 was 6,402 GWh and the generation of SET $_{>20\% \text{ units}}$ was 2,298 GWh, making up to 36% of total generation for Sabah.

The power plants/units listed under SET $_{5 \text{ units}}$ for Sarawak is shown in Figure 28 below.

**Figure 28: Set of 5 recent plants with generation of more than 20% of total generation in Sarawak**



As for Sarawak, there is no new thermal power plant constructed recently except listed above which were commissioned in 2009 and 2010. After 2010, only hydro power plants were built to supply electricity to the grid. The SET $_{5\ units}$ consists of two thermal power plants and two hydro power plants which supplied 22,028 GWh electricity to the grid. This amount was 88% of total generation of 24,978 GWh.

The emission factors for Build Margin that was calculated from the SET $_{5\ units}$ for all three regions are shown below.

**Table 10: Build Margin emission factor for 2017**

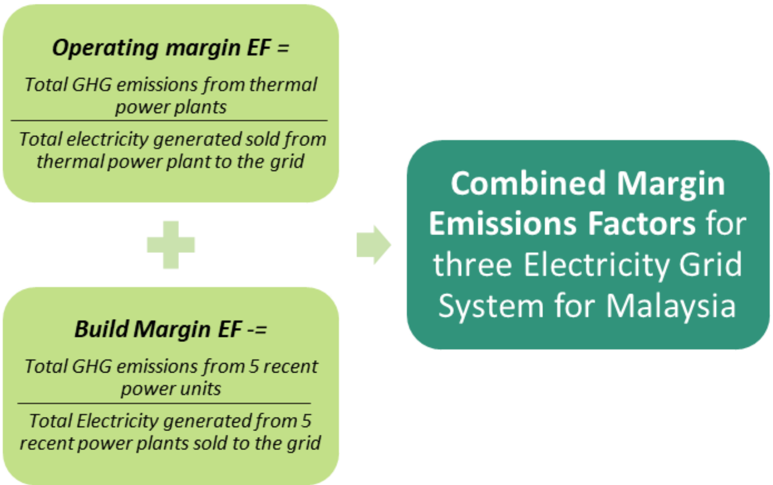
| Regions | Build Margin (BM) | | |
|---|---|---|---|
| | Total Generation (GWh) | Total Emissions (million $tCO_2$) | Build Margin ($tCO_2$/MWh) |
| Peninsular Malaysia | 24,636 | 12.9501 | 0.5257 |
| Sabah | 2,298 | 1.1182 | 0.4867 |
| Sarawak | 22,028 | 2.5965 | 0.1179 |

The BM emission factors based on fuel consumption for Peninsular Malaysia, Sabah and Sarawak are 0.526 $tCO_2$/MWh, 0.487 $tCO_2$/MWh and 0.118 $tCO_2$/MWh respectively. The BM emission factors will be weighted accordingly to calculate the combined margin.

### 5.2.4 Combined Margin

The combined margin emission factors are calculated for the purpose of quantifying GHG emissions baseline for electricity sector. In CDM Methodological Tool 7 Guideline, it is proposed a Combined Margin (CM) approach in which a simple average of the Operating Margin (OM) and Build Margin (BM) would apply to the first crediting period for CDM project, generally first seven years of operation, after which BM would apply. The OM refers to the effect of the project in operations. The BM refers to the effect of the project on capacity expansion (differing or avoiding capacity additions that would have taken place). The CM represents a blend of the OM and BM.

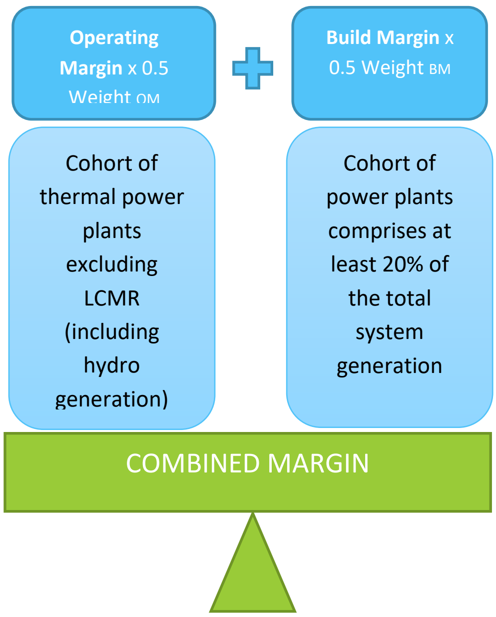
The calculation of the Combined Margin (CM) emission factor is based on the method shown below.




The Combined Margin emission factor for Malaysia was calculated as weighted average of the OM emission factor and the BM emission factor from 2005 until 2015. The weight of both OM and BM were chosen by default at 50%.

For Peninsular Malaysia and Sabah, the default value used is 50% for OM and 50% for BM to calculate Combine Margin emission factor. This is due to the current situation where the thermal power plants are dominating both regions.

**Figure 29: Weightage of OM and BM for Peninsular Malaysia & Sabah**




As for Sarawak, due to the electricity generation from hydro power plant is more than 50% of total electricity generation, the alternative weight was used since 2016. The weight of OM and BM that has been agreed to be used is 25% and 75% respectively.

**Figure 30: Weightage of OM and BM for Sarawak**

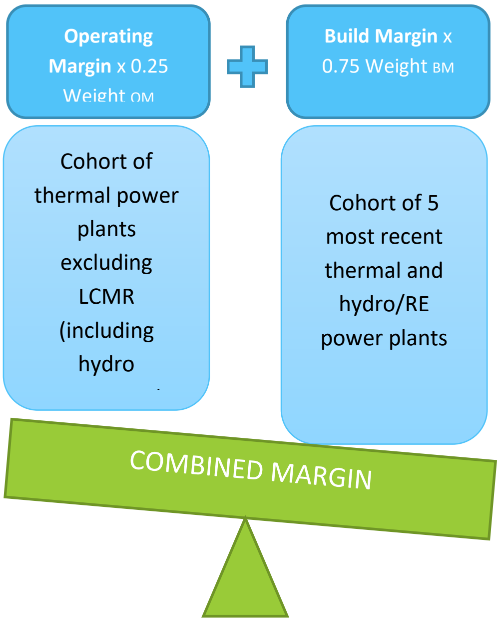



Table 11 shows the Combined Margin emission factor based on fuel consumption for Peninsular Malaysia is 0.585 $tCO_2/MWh$, while for Sabah and Sarawak are 0.525 $tCO_2MWh$ and 0.330 $tCO_2/MWh$ respectively.

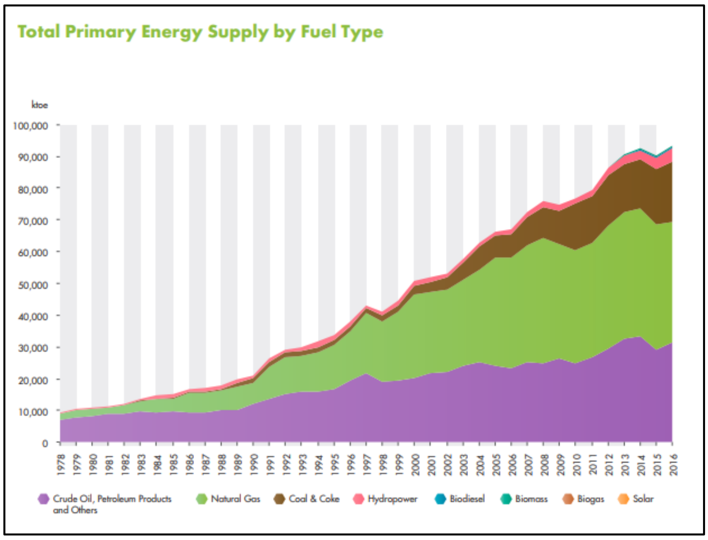
**Table 11: Combined Margin emission factor for 2017**

| Regions | Combined Margin (CM) ($tCO_2/MWh$) |
|---|---|
| Peninsular Malaysia | 0.585 |
| Sabah | 0.525 |
| Sarawak | 0.330 |

## 6. TREND ANALYSIS

Malaysia energy supply has increased significantly since 1970. As of 2016, the total primary energy supply in Malaysia reached 93,396 ktoe with natural gas contributing the biggest supply at 40.7% followed by coal, crude oil, petroleum products & others at 33.5% and coal & coke at 20,2%. Figure 31 illustrates the growth of energy supply in Malaysia.

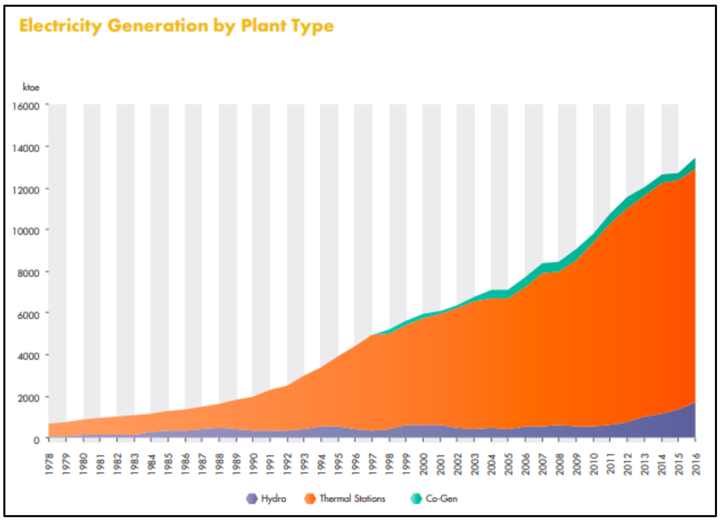
**Figure 31: Total energy supply by fuel type**




Source: Malaysia Energy Statistics Handbook 2018

In terms of type of technology of power plants, generation from thermal plants indicated significant increase compared with hydro and co-generation as shown in the Figure 32.

**Figure 32: Electricity generation by plant type**




Source: Malaysia Energy Statistics Handbook 2018

The $CO_2$ emission factors for each region have been derived and the information used to estimate the OM, BM and CM was extracted from studies conducted at GreenTech Malaysia and compiled in Tables 12, 13 and 14.

## Table 12: Operational Margin (OM)

Operational Margin

| Peninsular Malaysia | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| Generation, GWh | 89,338 | 85,421 | 89,241 | 90,215 | 92,244 | 100,510 | 97,372 | 108,642 | 109,340 | 110,000 | 103,561 | 114,470 | 111,698 |
| $CO_2$ Emission, kilo tonne | 52,489 | 51,809 | 56,410 | 56,322 | 57,773 | 72,363 | 70,285 | 75,706 | 76,013 | 72,725 | 65,084 | 75,867 | 71,830 |
| Emission Factor, $tCO_2/MWh$ | **0.588** | **0.607** | **0.632** | **0.624** | **0.626** | **0.720** | **0.722** | **0.697** | **0.659** | **0.638** | **0.629** | **0.663** | **0.643** |
| Average OM, $tCO_2/MWh$ | **0.592** | **0.613** | **0.611** | **0.603** | **0.618** | **0.657** | **0.689** | **0.713** | **0.681** | **0.653** | **0.637** | **0.644** | **0.645** |
| **Sarawak** | | | | | | | | | | | | | |
| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| Generation, GWh | 4,027 | 4,281 | 4,695 | 4,790 | 5,269 | 6,110 | 6,369 | 4,880 | 12,398 | 14,694 | 5,309 | 5,888 | 5,737 |
| $CO_2$ Emission, kilo tonne | 3,537 | 3,684 | 3,944 | 3,871 | 4,620 | 5,287 | 5,485 | 4,422 | 5,704 | 5,549 | 5,092 | 5,464 | 5,544 |
| Emission Factor, $tCO_2/MWh$ | **0.878** | **0.861** | **0.840** | **0.808** | **0.877** | **0.865** | **0.861** | **0.906** | **0.460** | **0.378** | **0.960** | **0.928** | **0.966** |
| Average OM, $tCO_2/MWh$ | **0.966** | **0.959** | **0.863** | **0.813** | **0.830** | **0.850** | **0.868** | **0.878** | **0.617** | **0.465** | **1.072** | **1.037** | **0.967** |
| **Sabah** | | | | | | | | | | | | | |
| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| Generation, MWh | 2,103 | 1,813 | 2,244 | 3,786 | 3,933 | 4,090 | 4,264 | 4,578 | 4,557 | 4,881 | 5,468 | 5,769 | 5,675 |
| $CO_2$ Emission, kilo tonne | 1,108 | 1,429 | 1,768 | 2,423 | 2,450 | 2,427 | 2,457 | 2,589 | 2,632 | 2,763 | 3,147 | 3,199 | 3,184 |
| Emission Factor, $tCO_2/MWh$ | **0.527** | **0.788** | **0.788** | **0.640** | **0.623** | **0.511** | **0.505** | **0.566** | **0.578** | **0.566** | **0.622** | **0.555** | **0.561** |
| Average OM, $tCO_2/MWh$ | **0.590** | **0.818** | **0.828** | **0.705** | **0.669** | **0.591** | **0.547** | **0.578** | **0.567** | **0.557** | **0.603** | **0.580** | **0.564** |

## Table 13: Build Margin (BM)

Build Margin

| Peninsular Malaysia | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| Generation, GWh | 33,291 | 26,389 | 33,207 | 36,120 | 43,768 | 52,075 | 47,690 | 57,061 | 51,171 | 35,301 | 37,535 | 24,170 | 24,636 |
| $CO_2$ Emission, kilo tonne | 21,178 | 18,735 | 25,145 | 26,781 | 32,745 | 44,975 | 38,334 | 43,884 | 41,067 | 25,958 | 25,581 | 16,664 | 12,950 |
| BM, $tCO_2/MWh$ | **0.636** | **0.710** | **0.757** | **0.741** | **0.748** | **0.864** | **0.804** | **0.769** | **0.803** | **0.735** | **0.682** | **0.707** | **0.526** |
| **Sarawak** | | | | | | | | | | | | | |
| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| Generation, GWh | 2,843 | 3,456 | 3,694 | 3,785 | 4,116 | 5,528 | 5,809 | 3,335 | 12,758 | 4,070 | 12,573 | 19,027 | 22,028 |
| $CO_2$ Emission, kilo tonne | 2,688 | 3,099 | 3,259 | 3,170 | 3,205 | 4,729 | 4,991 | 2,889 | 3,874 | 3,764 | 2,570 | 2,652 | 2,597 |
| BM, $tCO_2/MWh$ | **0.945** | **0.897** | **0.882** | **0.837** | **0.779** | **0.855** | **0.859** | **0.866** | **0.831** | **0.925** | **0.204** | **0.139** | **0.118** |
| **Sabah** | | | | | | | | | | | | | |
| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| Generation, MWh | 1,231 | 1,772 | 2,206 | 2,427 | 2,761 | 1,821 | 2,147 | 3,128 | 2,731 | 3,820 | 4,127 | 4,462 | 2,298 |
| $CO_2$ Emission, kilo tonne | 1,108 | 1,389 | 1,737 | 1,449 | 1,529 | 997 | 1,079 | 1,607 | 1,364 | 1,966 | 2,236 | 2,326 | 1,118 |
| BM, $tCO_2/MWh$ | **0.900** | **0.783** | **0.787** | **0.597** | **0.554** | **0.548** | **0.503** | **0.514** | **0.500** | **0.515** | **0.542** | **0.521** | **0.487** |

## Table 14: Combined Margin (CM)

Combined Margin

| Peninsular Malaysia | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| Generation, GWh | 93,526 | 84,906 | 89,241 | 90,215 | 92,244 | 100,510 | 97,372 | 108,642 | 115,849 | 114,111 | 110,945 | 117,545 | 119,977 |
| $CO_2$ Emission, kilo tonne | 52,489 | 51,809 | 56,410 | 56,322 | 57,773 | 72,363 | 70,285 | 75,706 | 76,013 | 72,725 | 65,084 | 75,867 | 71,830 |
| CM, $tCO_2/MWh$ | **0.614** | **0.661** | **0.684** | **0.672** | **0.683** | **0.760** | **0.747** | **0.741** | **0.742** | **0.694** | **0.659** | **0.667** | **0.585** |
| **Sarawak** | | | | | | | | | | | | | |
| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| Generation, GWh | 4,554 | 4,281 | 4,695 | 4,790 | 5,269 | 6,110 | 6,369 | 4,880 | 12,464 | 14,694 | 15,568 | 21,930 | 24,978 |
| $CO_2$ Emission, kilo tonne | 3,537 | 3,684 | 3,944 | 3,871 | 4,620 | 5,287 | 5,485 | 4,422 | 5,704 | 5,549 | 5,092 | 5,464 | 5,544 |
| CM, $tCO_2/MWh$ | **0.956** | **0.928** | **0.873** | **0.825** | **0.805** | **0.847** | **0.841** | **0.872** | **0.724** | **0.699** | **0.421** | **0.364** | **0.330** |
| **Sabah** | | | | | | | | | | | | | |
| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| Generation, GWh | 2,575 | 2,900 | 3,456 | 3,786 | 3,933 | 4,090 | 4,264 | 4,578 | 4,557 | 5,724 | 6,208 | 6,025 | 6,402 |
| $CO_2$ Emission, kilo tonne | 1,108 | 1,429 | 1,768 | 2,423 | 2,450 | 2,427 | 2,457 | 2,589 | 2,632 | 2,763 | 3,147 | 3,199 | 3,184 |
| CM, $tCO_2/MWh$ | **0.745** | **0.801** | **0.807** | **0.651** | **0.612** | **0.574** | **0.531** | **0.546** | **0.533** | **0.536** | **0.572** | **0.551** | **0.525** |

For improving power plant technology, an Ultra-Supercritical (USC) power plant has been introduced and developed in Malaysia. Three UCS coal-fired power plants operated in year 2017, namely Janamanjung Unit 5, Janamanjung Unit 4 or known as Generating Facility 2 and Tanjung Bin Energy Power Plant.

This clean coal technology has contributed less GHG emissions compared to conventional technology and improved the emission factor from the coal sector even though the usage of coal in generation mix is increasing every year.

The increase of electricity generation from renewable energy including hydroelectric power plant has significantly contributed to the decrease of emission factor especially for Sarawak and other regions. Hence, it shows that the emission factors for all three regions can be controlled by adopting more cleaner technology and low-emission measures in the country.

The emission factors resulting from the grid electricity generation is illustrated in Figures 33, 34 and 35 from 2005 until 2017 for Peninsular Malaysia, Sabah and Sarawak.

**Figure 33: $CO_2$ emission factors for power plants in Peninsular Malaysia**

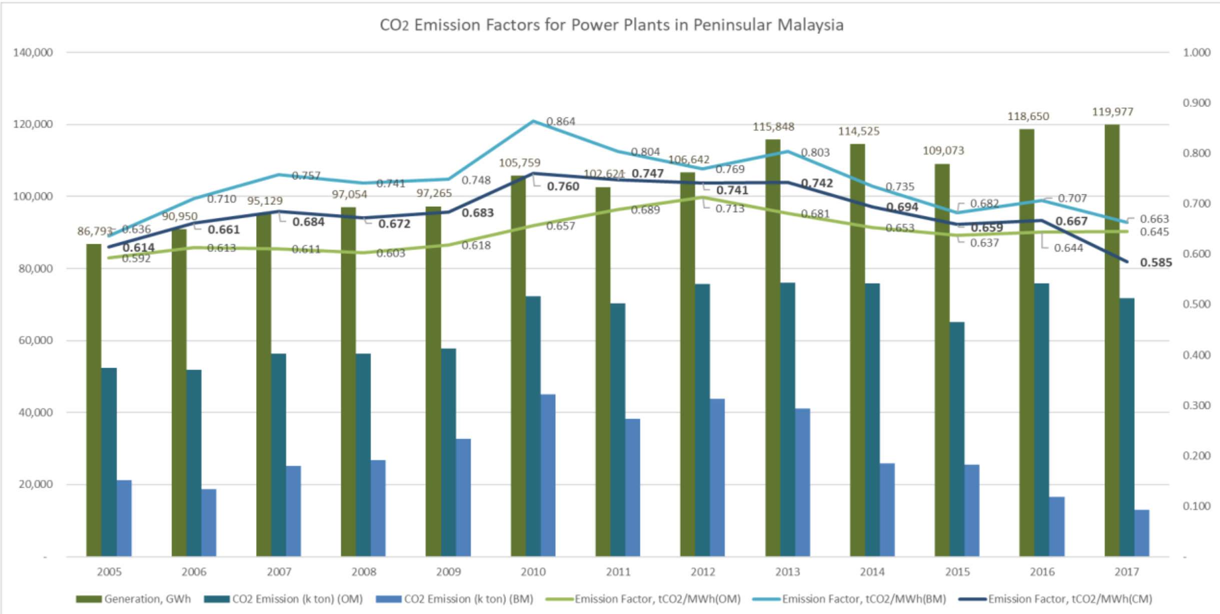



Figure 33 shows the $CO_2$ emission factors trend from year 2005 to 2017 for Peninsular Malaysia. The Combined Margin (CM) emission factor for year 2017 decreased by 13% compared to year 2016. While the electricity generation for that year increased by 1.1% in year 2017 compared to year 2016. For year 2017, an additional three power units was included in this calculation as follows:

- **TNB Ulu Jelai Hydroelectric Power Plant** (372MW) – commissioned in September 2016 (included in the calculation for year 2017)

- **Hulu Terengganu Hydroelectric Power Plant (Tembat)** – commissioned in December 2016 (included in the calculation for year 2017)
- **Janamanjung Unit 5** (Coal fired, 1,000MW) – commissioned in 2017 (included in the calculation for year 2017)

For 2017, the Net Calorific Value (NCV) for coal was provided with more specific data based on power plant/unit. The more specific data helps to provide more accurate $CO_2$ co-efficient emissions and findings for this study.

**Figure 34: $CO_2$ emission factors for power plants in Sabah**

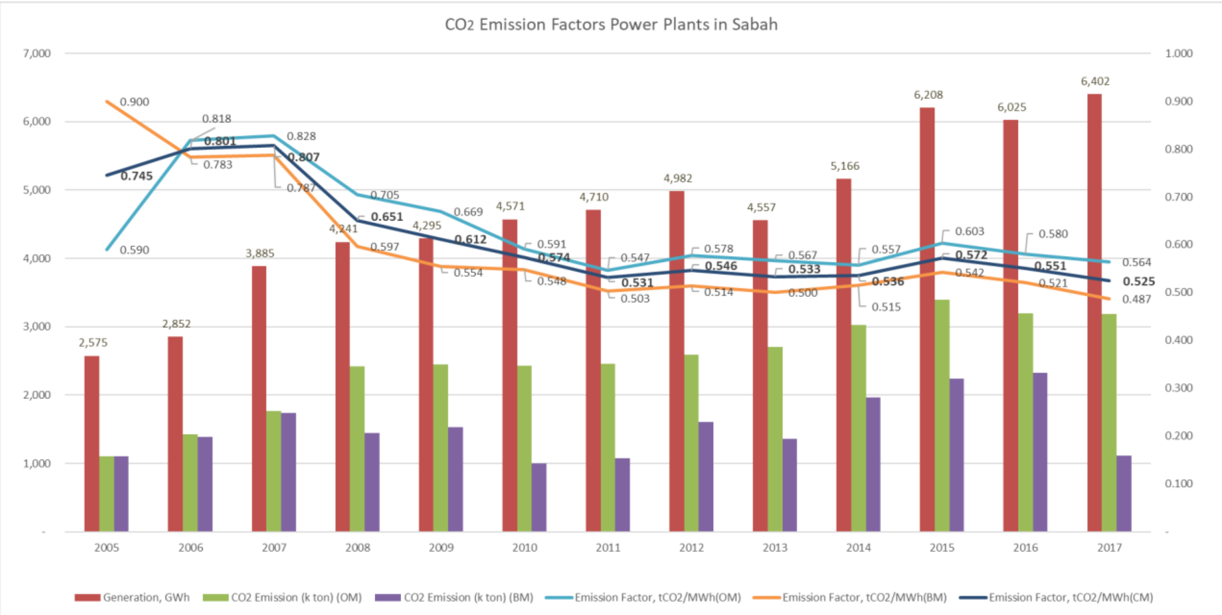



Figure 34 shows the $CO_2$ emission factors trend from year 2005 to 2017 for Sabah. The Combined Margin (CM) emission factor for year 2017 decreased by 5% compared to year 2016. While the electricity generation for that year increased by 6% in year 2017 compared to year 2016. For year 2017, an additional new power unit and Large-Scale Solar (LSS) project was included in this calculation as follows:

- **Sandakan Power Station Gantisan GT1** (Diesel,18MW) - commissioned in December 2017 (included in the calculation for year 2017)
- **Tadau 2MW (LSS)** – commissioned in September 2017 (included in the calculation for year 2017)

Other than that, the 21-years Power Purchased Agreement (PPA) between ARL Power and SEB ended on 30 October 2016. ARL Power, which is one of the Independent Power Producer (IPP) in Sabah, operated a diesel power plant with capacity of 50MW.

For 2017, the Net Calorific Value (NCV) for Medium Fuel Oil (MFO) provided by SESB is more specific data which is based on power plant/unit. Therefore, it helps in providing more accurate findings for this study.

**Figure 35: $CO_2$ emission factors for power plants in Sarawak**

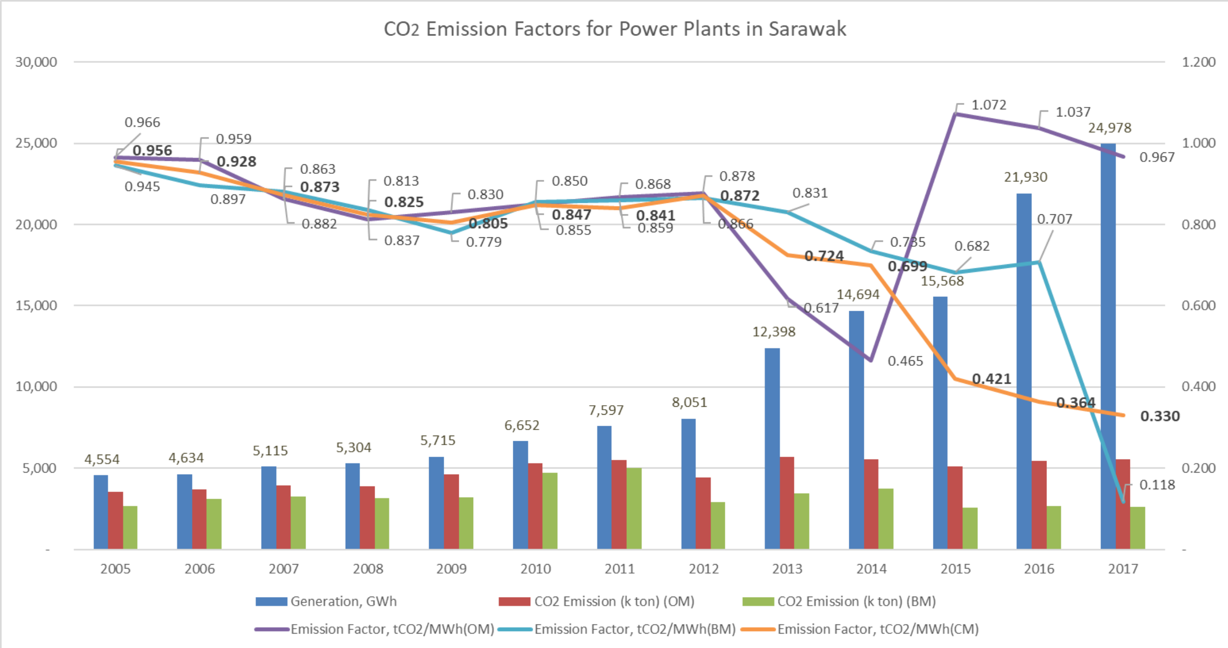



Figure 35 shows the $CO_2$ emission factors trend from year 2005 to 2017 for Sarawak. The Combined Margin (CM) emission factor for year 2017 decreased by 9% compared to year 2016. While the electricity generation for that year increased by 14% in year 2017 compared to year 2016 with due to the increase of hydro generation of Bakun and Murum Hydroelectric Power Plant. For this study, the Net Calorific Value (NCV) for Diesel and Coal which was provided by SEB is more specific data based on power plant/unit. Thus, it helps in providing more accurate emission factor for this study.

# 7. CONCLUSION

The analysis for CDM Electricity Baseline for 2017 was calculated by using CDM Methodological Tool 7.0. This emission factors will be used to account for the CDM energy project for the carbon emission reduction for electricity related mitigation actions. Table 15 shows the findings of Combined Margin (CM) emission factor for three regions in Malaysia.

**Table 15: Combined Margin (CM) emission factor**

| Regions | Combined Margin (CM) |
|---|---|
| | $tCO_2/MWh$ |
| Peninsular Malaysia (50% OM + 50% BM) | 0.585 |
| Sabah (50% OM + 50% BM) | 0.525 |
| Sarawak (25% OM + 75% BM) | 0.330 |

Note: The emission factor for Sarawak is calculated based on annual NCVs data provided by SEB. The selection of emission factors for type of fuel was based on the NCV's range from 2006 IPCC Guidelines.

Trend analysis of emission factors for this study is a comparative analysis to measure performance of emission factor for each region in Malaysia. Thus, the analysis and findings from this study will help relevant stakeholders including policy makers or government officers to make comparison of GHG emissions, fuel combustion for power generation and growth of green technologies over a time period and also will be a reference for future planning on reducing emissions from energy industries in Malaysia.

For Peninsular Malaysia, coal remained as the major source of electricity generation with a share of 54% followed by natural gas with a share of 40% from total generation. The fuel consumption from coal increasing from year to year with increment of 10% for year 2017 compared to 2016. Until 2017, four (4) Ultra Super Critical (USC) Coal-Fired Power Plant was developed in Peninsular Malaysia which increases the plant efficiency from coal-fired power plant and at the same time improves the emission factors.

For Sabah, natural gas is still a major source of electricity generation with a share of 86% followed by hydropower with a share of 5% from total generation.

In Sarawak, hydropower generation remained the major source of electricity generation supplied to the grid with a share of 77% followed by natural gas with a share of 11.5% from total generation.

# 8. REFERENCES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