Carbon Emissions

Key Stage: 3

Strand: Number and Algebra

Learning Unit: Laws of Integral Indices (scientific notations)

Objective: To apply laws of integral indices to solve real-life problems

Prerequisite Knowledge: Using Percentages

Relationship with other KLA(s) in STEM Education:

(i) The topic "Energy sources" in Unit 5 "Energy" of Science at junior secondary

(ii) The topic "Air quality" in Unit 7 "Living things and Air" of Science at junior secondary

Description of the Activity:

To compare the carbon emissions and air emissions when generating electricity by different fuels.

Activity

Carbon emissions refer to carbon dioxide emissions. Carbon dioxide is a kind of greenhouse gas that contributes to climate change. **Air emissions** refer to the emission of air pollutants. At present, the Government monitors emission of the following pollutants: Sulphur dioxide (SO_2), nitrogen oxide (NOx), respirable suspended particulates (RSP/PM10), fine suspended particulates (FSP/PM2.5), volatile organic compounds (VOC) and carbon monoxide (CO).

According to the figures of CLP Power Hong Kong Limited in 2016, 34442 GWh electricity sold. The outputs between electricity generated and sold by different fuels and their carbon emissions and air emissions are as follows:

Power Stations	Fuel Type	Electricity Output by Generation Fuel Type
Castle Peak Power Station	Coal	41%
Daya Bay Nuclear Power Station	Nuclear	32%
Black Point Power Station	Natural Gas	26%
Penny's Bay Power Station	Oil	0.003%
Guangzhou Pumped Storage Power Station	Hydro	0.997%

Table 1. Electricity output by generation fuel type in 2016

Power Stations	Carbon Emissions (kT)	Air Emissions (kT)			
	CO_2	SO_2	NOx	Particulates (Total)	Particulates (Respirable)
Castle Peak Power Station	14737	5.2	15.4	0.5	0.3
Black Point Power Station	3745	0.05	1.6	0.06	0.06
Penny's Bay Power Station	1.2	5×10^{-6}	1.8×10^{-3}	3×10^{-5}	3×10^{-5}

Table 2. Emissions performance of CLP's power stations in Hong Kong in 2016

Remarks:

1. The unit Wh stands for watt-hour, which is a unit of energy.
   $1\ GWh = 1 \times 10^9\ Wh$ and $1\ kWh = 1 \times 10^3\ Wh$.
2. The unit T stands for tonne.
   $1\ T = 1 \times 10^3\ kg$ and $1\ kT = 1 \times 10^3\ T$.

1. Given that the total electricity sold by CLP in 2016 was 34442 GWh. Calculate the amount of electricity sold by each fuel type, correct to 2 decimal places if necessary.

Power Stations	Fuel Type	Electricity Output by Generation Fuel Type	Amount of Electricity Sold (GWh)
Castle Peak Power Station	Coal	41%	
Daya Bay Nuclear Power Station	Nuclear	32%	
Black Point Power Station	Natural Gas	26%	
Penny's Bay Power Station	Oil	0.003%	
Guangzhou Pumped Storage Power Station	Hydro	0.997%	

2. Refer to the emissions performance of CLP's power stations in Hong Kong in Table 2, calculate the carbon emissions (kg) and air emissions (kg) per unit of electricity (kWh) sold which generated by coal and natural gas in the following table. Correct your answers to 3 significant figures and express the answers in scientific notation.

Power Stations	Fuel Type	Carbon Emissions (kg)	Air Emissions (kg)			
		CO_2	SO_2	NOx	Particulates (Total)	Particulates (Respirable)
Castle Peak	Coal					
Black Point	Natural Gas					

3. Using the results of Q.2:
   (a) Compare the carbon emissions per unit of electricity generated by coal and that by natural gas through telling by how many times is one when compared with the other. Correct your answer to 1 decimal place.

(b) Without actual calculation, tell among the air emissions, sulphur dioxide, nitrogen oxide and particulates, which one has the greatest difference in emission per unit of electricity between the use of coal and natural gas.

4. Assume that carbon emissions by nuclear power and hydro power are zero,
   (a) Calculate the average carbon emissions (kg) per unit of electricity (kWh) sold. Correct your answer to 2 decimal places.
   (b) According to the chart of average daily electricity consumption in your electricity bill, calculate the maximum and minimum average daily carbon emissions attributed to your household in past years. You may also investigate the carbon emissions of an 8-hour operation of a household air conditioner in summer night by the information on the energy label of an air conditioner.
   (c) If CLP replace coal with natural gas in electricity generation, will the average carbon emissions per unit of electricity sold be halved?

Notes for Teachers:

Teachers may refer to page 48 of the *CLP Information Kit* (https://www.clp.com.hk/infokit-EN) for more information about the properties of using different fuels for electricity generation.

Suggested answers:

1. Given that the total electricity sold by CLP in 2016 was 34442 GWh. Calculate the amount of electricity sold by each fuel type, correct to 2 decimal places if necessary.

Power Stations	Fuel Type	Electricity Output by Generation Fuel Type	Amount of Electricity Sold (GWh)
Castle Peak Power Station	Coal	41%	14121.22
Daya Bay Nuclear Power Station	Nuclear	32%	11021.44
Black Point Power Station	Natural Gas	26%	8954.92
Penny's Bay Power Station	Oil	0.003%	1.03
Guangzhou Pumped Storage Power Station	Hydro	0.997%	343.39

2. Refer to the emissions performance of CLP's power stations in Hong Kong in Table 2, calculate the carbon emissions (kg) and air emissions (kg) per unit of electricity (kWh) sold which generated by coal and natural gas in the following table. Correct your answers to 3 significant figures and express the answers in scientific notation.

Power Stations	Fuel Type	Carbon Emissions (kg)	Air Emissions (kg)			
		CO_2	SO_2	NOx	Particulates (Total)	Particulates (Respirable)
Castle Peak	Coal	1.04	3.68×10^{-4}	1.09×10^{-3}	3.54×10^{-5}	2.12×10^{-5}
Black Point	Natural Gas	4.18×10^{-1}	5.58×10^{-6}	1.79×10^{-4}	6.70×10^{-6}	6.70×10^{-6}

3. Using the results of Q.2:

(a) Compare the carbon emissions per unit of electricity generated by coal and that by natural gas. Express your answer through telling by how many times is one when compared with the other. Correct your answer to 1 decimal place.

$$\frac{1.04}{0.418}$$

≈ 2.5

$\therefore$ The carbon emissions of the electricity generated by coal is about 2.5 times of those by natural gas.

(b) Without actual calculation, tell among the air emissions, sulphur dioxide, nitrogen oxide and particulates, which one has the greatest difference in emission per unit of electricity between the use of coal and natural gas.

According to answers in Q.2, sulphur dioxide (SO_2) has the greatest difference in emission since the difference in index between coal and natural gas are larger than that of other emissions.

4. Assume that carbon emissions by nuclear power and hydro power are zero,

(a) Calculate the average carbon emissions (kg) per unit of electricity (kWh) sold. Correct your answer to 2 decimal places.

The average carbon emissions per unit of electricity sold

$$= \frac{(14737 + 3745 + 1.2) \times 10^6}{34442 \times 10^6} \text{ kg / kWh}$$

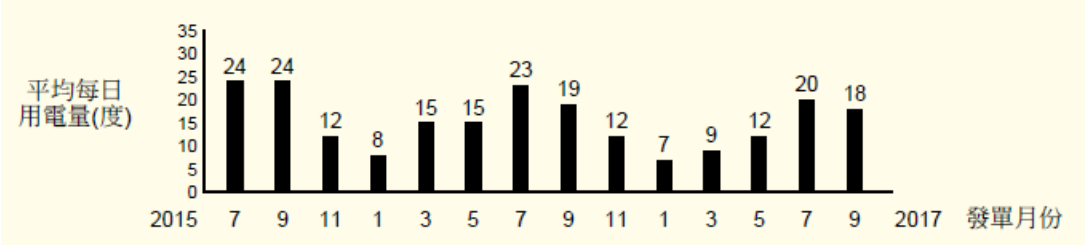
$$= \frac{18483.2}{34442} \text{ kg / kWh}$$

$= 0.5366$ kg / kWh

≈ 0.54 kg / kWh

(b) According to the chart of average daily electricity consumption in your electricity bill, calculate the maximum and minimum average daily carbon emissions attributed to your household in past years. You may also investigate the carbon emission of an 8-hour operation of a household air conditioner in summer night by the information on the energy label of an air conditioner.

Notes: This is an open-ended question. Teachers may compare the carbon emissions produced by different households. Teachers may also discuss with students why the carbon emissions in summer are higher than that in winter.



According to my electricity bill,

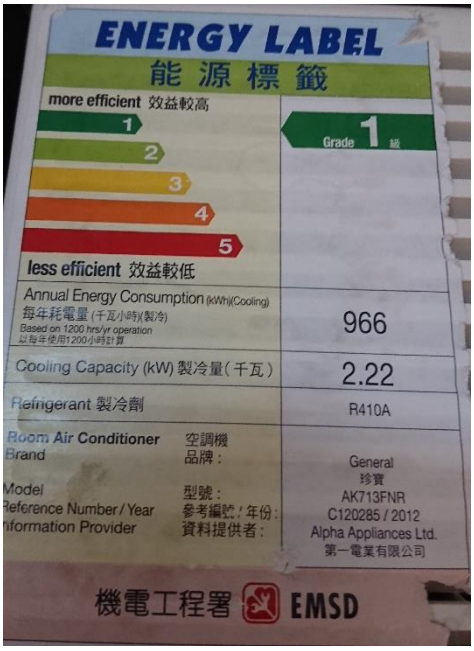
The maximum average daily carbon emission $= (24 \times 0.5366)$ kg

$= 12.88$ kg

The minimum average daily carbon emission $= (7 \times 0.5366)$ kg

$= 3.76$ kg

Air conditioners are used in summer which will increase the amount of electricity and the carbon emissions.



According to the energy label of an air conditioner, the determination of annual energy consumption is based on a 1200 hours/year operation.

Annual energy consumption = 966 kWh

If an air conditioner operates 8 hours per night in summer, the carbon emissions for a night is

$$\left(\frac{966}{1200} \times 8 \times 0.5366\right) \text{kg}$$

≈ 3.46 kg

(c) If CLP replaces coal with natural gas in electricity generation, will the average carbon emissions per unit of electricity sold be halved?

If coal is replaced by natural gas, assume the percentages in Table 1 is kept unchanged (i.e. a total of 67% (41% + 26%) of electricity is generated by natural gas), the carbon emissions from generation of electricity by natural gas is

$$(3745 \times \frac{41+26}{26})\text{kT}$$

$= 9650.5769$ kT

The average carbon emissions per unit of electricity sold

$$= \frac{(9650.5769 + 1.2) \times 10^6}{34442 \times 10^6} \text{ kg/kWh}$$

$= 0.2802$ kg/kWh

≈ 0.28 kg/kWh

The percentage decrease in average emissions

$$= \frac{0.5366 - 0.2802}{0.5366} \times 100\%$$

$= 47.78\%$

$\therefore$ The average carbon emissions per unit of electricity sold will not be halved, but the reduction is nearly half of the existing one.

References:

CLP Power Hong Kong Limited. (2016). *2016 Sustainability Report*. Retrieved from CLP website: https://www.clpgroup.com/en/sustainability/sustainability-reports

CLP Power Hong Kong Limited. (2017). *CLP Information Kit*. Retrieved from CLP website: https://www.clp.com.hk/infokit-EN