TUTORIAL:
CARBON FOOTPRINT

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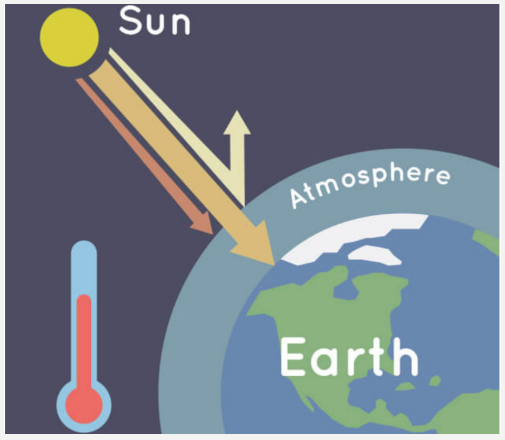
CARBON FOOTPRINT

- **A carbon footprint** is the total *greenhouse gas (GHG) emissions* caused by an individual, event, organization, service, or product, expressed as carbon dioxide equivalent.
- **How can I reduce my carbon footprint?**
  - Driving more-efficient vehicles (or making sure that your current vehicles are properly maintained),
  - Taking public transportation,
  - Using energy-efficient appliances,
  - Insulating your home to reduce heating and air conditioning costs,
  - Consuming food that doesn't require as much transportation,
  - Eating less meat, which has a higher carbon footprint than fruits and vegetables.

GHG EMISSIONS

- **Greenhouse Gas (GHG):**
  - any gas in the atmosphere which absorbs and re-emits heat, and thereby keeps the planet's atmosphere warmer than it otherwise would be.
  - any gaseous compound in the atmosphere that is capable of absorbing infrared radiation, thereby trapping and holding heat in the atmosphere. By increasing the heat in the atmosphere, greenhouse gases are responsible for the greenhouse effect, which ultimately leads to global warming.
- **Greenhouse Effect:** is a process that occurs when gases in Earth's atmosphere trap the Sun's heat.



- **The main GHGs in the Earth's atmosphere are:** water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone.

QUESTION 1:

A 915 MW power station with an electrical load factor of 72.4% (how much of the power station is actually used) and a thermal efficiency of 40% uses coal as a fuel source. The coal has properties as given in the table:

Moisture	Ash	Carbon	Hydrogen	Nitrogen	Sulphur	Oxygen	Calorific value
8%	7.7%	77.0%	3.0%	0.2%	1.0%	2.05%	29.7 MJ/kg

How much CO2 and NO2 are produced by the station (assuming all N from coal converted to NO2 with no additional NO2 from combustion)?. Using the emissions table below what is the **direct hourly CO2 equivalent** (t CO2-e) of these greenhouse gases?

Greenhouse gas	Global warming potential
CO_2	1
CH_4	21
NO_x	310

Note: Atomic mass of C=12, O=16, N=14; 1 kW = 1000 J

Answer:

$$Power = (915x10^3 kW)\left(1000\frac{J/s}{kW}\right) = \left(915x10^6\frac{J}{s}\right) = 915\frac{MJ}{s}\ x\ 60\ s/m\ x\ 60\ m/hr = \mathbf{3294x10^3 MJ/hr}$$

$$Coal\ req. = \frac{Power\ x\ Load\ Factor}{Thermal\ efficiency\ x\ Calorific\ Value} = \frac{\left(3294x10^3\frac{MJ}{hr}\right)(0.724)}{(0.4)(29.7\frac{MJ}{kg})} = 201000\frac{\text{kg}}{\text{hr}} = \mathbf{201}\frac{\mathbf{tonne}}{\mathbf{hr}}$$

$$CO2\ prod = Coal\ req\ x\ Coal\ Properties\ x\ \frac{Molar\ Mass}{Molar\ mass\ of\ property} = (201)(0.77)\left(\frac{12+(16x2)}{12}\right) = 568\frac{tonne}{hr}$$

$$NO2\ prod = Coal\ req\ x\ Coal\ Properties\ x\ \frac{Molar\ Mass}{Molar\ mass\ of\ property} = (201)(0.002)\left(\frac{14+(16x2)}{14}\right) = 1.3\ \frac{tonne}{hr}$$

$$\mathbf{CO2\ equi.} = (\mathbf{CO2\ prod})(\mathbf{GWPotential}) = (\mathbf{568*1}) + (\mathbf{1.3*310}) = \mathbf{568+403} = \mathbf{971}\frac{\mathbf{tonne}}{\mathbf{hr}}$$

QUESTION 2:

If the same power station uses natural gas with the characteristics in the following table as fuel what is the hourly CO2 equivalent (t CO2-e)?

Moisture	Ash	Carbon	Hydrogen	Sulphur	Nitrogen	Calorific value
0.3%	0.4%	83.2%	11.3%	2.8%	0.1%	40.5 MJ/kg

Note: Atomic mass of C=12, O=16, N=14; 1 kW = 1000 J

Greenhouse gas	Global warming potential
CO_2	1
CH_4	21
NO_x	310

Answer:

$$Power = (915x10^3 kW)\left(1000\frac{J/s}{kW}\right) = \left(915x10^6\frac{J}{s}\right) = 916\frac{MJ}{s}\ x\ 60\ s/m\ x\ 60\ m/hr = \mathbf{3294x10^3 MJ/hr}$$

$$Coal\ req. = \frac{Power\ x\ Load\ Factor}{Thermal\ efficiency\ x\ Calorific\ Value} = \frac{\left(3294x10^3\frac{MJ}{hr}\right)(0.724)}{(0.4)(40.5\frac{MJ}{kg})} = 147000\frac{\text{kg}}{\text{hr}} = \mathbf{147}\frac{\mathbf{tonne}}{\mathbf{hr}}$$

$$CO2\ prod = Coal\ req\ x\ Coal\ Properties\ x\ \frac{Molar\ Mass}{Molar\ mass\ of\ property} = (147)(0.832)\left(\frac{12+(16x2)}{12}\right) = 448\frac{tonne}{hr}$$

$$NO2\ prod = (147)(0.001)\left(\frac{14+(16x2)}{14}\right) = 0.48\ \frac{tonne}{hr}$$

$$\boldsymbol{CO2\ equi.} = (\boldsymbol{CO2\ prod})(\boldsymbol{GWPotential}) = (\mathbf{448}*\mathbf{1}) + (\mathbf{0.48}*\mathbf{310}) = \mathbf{448+149} = \mathbf{597}\frac{\boldsymbol{tonne}}{\boldsymbol{hr}}$$

QUESTION 3:

Calculate the emissions generated (t CO2-e) from Natural Gas Consumption if a Victorian Hotel uses 9000 GJ of natural gas per annum. Use the data from the following table.

Table 2 Emissions from the consumption of natural gas *

	Small user < 100,000 GJ pa		Large user > 100,000 GJ pa	
State	**Point source EF (a)**	**Full fuel cycle EF (b)**	**Point source EF (a)**	**Full fuel cycle EF (b)**
	A	B	C	D
	kg CO_2-e/GJ	kg CO_2-e/GJ	kg CO_2-e/GJ	kg CO_2-e/GJ
NSW & ACT	51.7	71.3	51.7	68.0
Victoria	51.9	63.6	51.9	63.4
Queensland	52.6	68.8	52.6	64.2
SA	51.7	73.8	51.7	71.2
WA	52.7	60.7	52.7	60.0
TAS	NA	NA	NA	NA
NT	52.0	53.6	52.0	53.5

* For reporting under the **Greenhouse Challenge and Greenhouse Friendly Certification**, *Full Fuel Cycle* emission factors should be used, (either column B or D depending on the size of the user).

Source: George Wilkenfeld 2004.

Answer:

$$\textbf{Formula: } \boldsymbol{GHG\ Emissions(tCO2-e) = Q\ x \frac{EF}{1000}}$$

$$; where\ Q: quantity\ of\ natural\ gas\ consumed\ in\ GJ, EF: Emission\ Factor$$

Since the hotel used 9000 GJ, it is under 100,000, which means it is a Small user.

$$GHG\ Emissions\ for\ hotel = 9000\ x \frac{63.6}{1000} = \boldsymbol{572\ tCO2-e}$$

QUESTION 4:

A New South Wales freight company consumes 2400 kL of petrol and 2400 kL automotive diesel(transport) per annum. Using data from the following table calculate the direct GHG emissions for the company.

Table 3 Fuel Combustion emission factors (Transport Fuels) *

Fuel	Energy content	Point source EF		Full fuel cycle EF	
	A	B	C	D	E
	GJ/kL	kg CO_2-e/GJ	t CO_2-e/kL	t CO_2-e/GJ	t CO_2-e/kL
Automotive Gasoline	34.2	73.5	2.5	81.2	2.8
Automotive Diesel Oil	38.6	70.5	2.7	78.2	3.0
Aviation Gasoline	33.1	69.5	2.3	77.2	2.6
Aviation Turbine	36.8	70.4	2.6	78.1	2.9
Industrial diesel fuel	39.6	70.5	2.8	78.2	3.1
Fuel Oil	40.8	74.3	3.0	82.0	3.3
LPG	25.7	60.5	1.6	68.3	1.8
Natural gas (LV)	39.5 (a)	57.2	2.3 (b)	68.6	2.7
Natural Gas (HV)	39.5 (a)	53.8	2.1 (b)	65.2	2.6

Answer:

$Formula\ for\ direct\ GHG\ emissions: Emissions(t\ CO2 - e) = QxEF\left(CO2 - \frac{e}{kL}\right)$

$Petrol = 2400\ kL\ x\ 2.5 = 6000\ t\ CO2 - e$

$Diesel = 2400\ kL\ x\ 2.7 = 6480\ t\ CO2 - e$

$\boldsymbol{Total\ GHG\ Emissions = 6000 + 6480 = 12480\ t\ CO2 - e}$