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Assignment #2: Climate change

1. (a) Global energy supply from fossil fuels $= 300 \times 10^{15}$ kJ

1kg fossil fuel has average energy content $= 40000$ kJ

$\therefore$ For producing 300×10^{15} kJ energy globally, we require

$$\left(\frac{1}{40000 \text{ kJ}} \times 300 \times 10^{15} \text{ kJ}\right) \text{kg} = \frac{3 \times 10^{13}}{4} \text{ kg}$$

$$= \underline{75 \times 10^{11} \text{ kg}}$$

Burning C_3H_5 (fossil fuel) in Oxygen,

$$4C_3H_5 + 17O_2 \longrightarrow 12CO_2 + 10H_2O$$

$\therefore$ $4(3\times12+5\times1)$g of C_3H_5 produces $12(12+2\times16)$ g of CO_2

$\Rightarrow$ 164 g of C_3H_5 produces 528 g of CO_2

$\Rightarrow$ 75×10^{11} kg of C_3H_5 produces $\left(\frac{528 \text{ g}}{164 \text{ g}} \times 75 \times 10^{11} \text{ kg}\right) CO_2$

$$= \underline{\underline{241.463 \times 10^{11} \text{ kg } CO_2}}$$

$\therefore$ CO_2 released in 2013 by burning fossil fuels $= \underline{\underline{241.463 \times 10^{11} \text{ kg}}}$

(b) $PV = nRT$ (R = constant)

At constant pressure and temperature,

$$V \propto n$$

$$\therefore \frac{V_{CO_2}}{V_{air}} = \frac{N_{CO_2}}{N_{air}} = \frac{\left(\dfrac{2.41463 \times 10^{13} \times 10^{3}\ g}{44\ g/mol}\right)}{\left(\dfrac{5 \times 10^{18} \times 10^{3}\ g}{29\ g/mol}\right)} \times 10^{6}\ ppm$$

$$= 0.31829 \times 10^{22-18-3}\ ppm$$

$$= 3.1829\ ppm$$

$$= \underline{\underline{3.18\ ppm}}$$

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2. (i) Given, Global Surface Warming $\Delta T = 2°C = 2K$

Also $\Delta F = 5.35 \ln\left(\frac{C}{280}\right) = \Delta Q + \lambda \Delta T = k\Delta T + \lambda \Delta T$

$\Rightarrow 5.35 \ln\left(\frac{C}{280}\right) = (0.6 + 1.4)\ W/m^2 K \times 2K$

$\Rightarrow 5.35 \ln\left(\frac{C}{280}\right) = 4\ W/m^2 \Rightarrow C = 280 \ln^{-1}\left(\frac{4}{5.35}\right)$ ppm

$= 280 \times 2.1120$ ppm

$= \cancel{591.38\ ppm}$

CO_2 concentration for temperature target of 2°C above pre industrial $= C = 591.38$ ppm

(ii) 1ppm of CO_2 concentration requires 2.1 Gt C

Increase in $CO_2 = (591.38 - 280)$ ppm

$\Rightarrow (591.38 - 280)$ ppm of CO_2 requires $(2.1)(591.38 - 280)$ Gt C

$\Rightarrow ((591.38 - 280) \times 2)$ ppm of CO_2 requires $(2.1)(591.38 - 280)(2)$ Gt C

[50% of CO_2 is taken up by ocean and biosphere]

$\therefore$ Emissions $= (2.1)(591.38)(2)$ GtC $- (2.1)(280)(2)$

$= 2483.796$ GtC $- (2.1)(2)(280)$ GtC

$= 1307.796$ Gt C

(iii) to achieve 2°C target, 1.5°C increase is due to CO_2 emission and rest 0.5°C is due to non CO_2 forcings.

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$\therefore$ CO_2 concentration↑ for temperature increase of 1.5 °C $= 280\left[\ln^{-1}\left(\frac{2\times1.5}{5.35}\right)-1\right]$

$\rightarrow c = 280\left[\ln^{-1}\left(\frac{3}{5.35}\right)-1\right]$

$\rightarrow c = (490.55493 \text{ ppm} - 280)$

1 ppm CO_2 requires 2.1 GtC

$\rightarrow$ c ppm CO_2 requires $(2.1)(c)$ Gt C

$\Rightarrow$ 2c ppm CO_2 requires $(2.1)(c)(2)$ GtC [50% is absorbed by ocean]

$\therefore$ Total emissions $= (2.1)\left(280\left[\ln^{-1}\left(\frac{3}{5.35}\right)-1\right]\right)(2)$ GtC

$= \underline{\underline{884.33 \text{ GtC}}}$

Given, 540 GtC has already been emitted so far,

$\therefore$ Remaining Carbon budget $= (884.33 - 540)$ GtC

$= \underline{\underline{344.33 \text{ GtC}}}$

(iv) For $(k+\lambda) = 1.8$,

CO_2 concentration for temperature increase of 1.5°C $= 280\left[\ln^{-1}\left(\frac{(1.8)(1.5)}{5.35}\right)\right]$ ppm -280

$\rightarrow c = 280\left[\ln^{-1}\left(\frac{1.8\times1.5}{5.35}\right)-1\right]$ ppm

1 ppm CO_2 requires 2.1 GtC

$\rightarrow$ c ppm CO_2 requires $(2.1c)$ GtC

→ 2c ppm CO_2 requires $(2.1)(c)(2)$
[50% is taken up by ocean and biosphere]

∴ Total emissions $= (2.1)\left(280\left(\ln^{-1}\left(\frac{1.8 \times 1.5}{5.35}\right)-1\right)\right)(2)$ GtC

$= 771.98$ GtC

Given,

1 year $= 10$ GtC

Remaining Carbon budget $= (771.98 - 540)$ GtC
$= \underline{231.98 \text{ GtC}}$

∴ No. of years $= \frac{231.98}{10}$ years $= \underline{23 \text{ years}}$