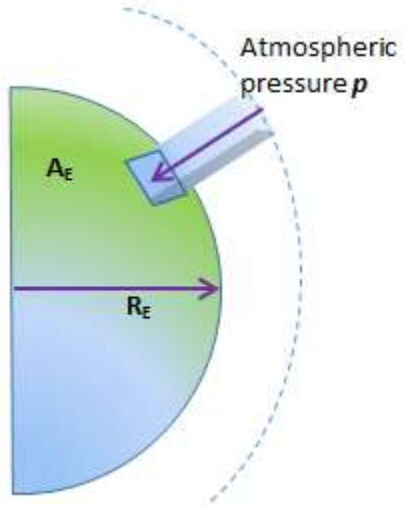
Due: Oct. 2, 2024

Energy: Science, Technology, and Society

Homework Set 2

1. Atmospheric Carbon Content



The global average of CO_2 in the atmosphere has currently (2023) a value of $[CO_2]$=419.3 ppmv (parts per million in volume). Calculate the total CO_2 and the carbon content (in metric tons) of the atmosphere, if CO_2 were the only carbon carrier in the atmosphere. Air is a mixture of many gases whose weighted mean molecular weight is $M_{air}=29 g/mol$. In the calculation use the atmospheric pressure which equals the weight of $1.033 \cdot 10^4$ kg/m^2. The mean radius of Earth is R_E=6371 km.

2. GHG Emission Standards

Coal has a good heating value of 30 MJ/kg but comes with various contaminants that affect the emission of undesirable greenhouse gases such as SO_2 or NO_2. Emission standards adopted in the 1970s set limits of 516g for SO_2 per GJ of total energy produced in coal burners and 260 g/GJ for NO_2.

A certain coal has the effective molecular composition $C_{100}H_{100}S_1N_{0.5}$. Calculate the emission rates for SO_2 and NO_2 in g/GJ for this coal. Is the burner in compliance with the standards?

Useful material data: https://webbook.nist.gov/cgi/cbook.cgi?ID=C124389&Units=SI

3. Proposal tp Mitigate CO_2 Emission by Geo-Engineering (Parasol)

Estimated radiative forcings (in W/m^2) at Earth's surface in 2030 due to future greenhouse gas emissions suggest that the effect of a doubling of the CO_2 concentration relative to the emissions up to 1990 ($= 10^{12}$ t C) is equivalent to only a few percent additional radiative influx from the Sun. Therefore, a dimming of sunlight by a few percent, e.g., with an artificial "parasol" could offset, or significantly reduce, the effects of future GHG emissions. The parasol material would have to be placed into a low-Earth orbit, where it could remain for a period of 2 years. The current cost of launching 1 kg of payload into orbit is approximately $10k.

a) Estimate the annual total cost of a geo-engineering scheme, whereby a screen of totally reflective aerosol particles (1μ diameter, mass density $\rho = 1 g/cm^3$) is constructed around Earth at an altitude of 200 km, corresponding to a low Earth orbit.

b) Estimate the "carbon tax" in $\$/tCO_2$ that would have to be raised by the emitters to pay for a parasol, to compensate for the effect caused by the average emitter over two years.

c) Consider reforestation of land as a geo-engineering CO_2 sequestration alternative. Using the information available in the published Keeling curve to make a rough estimate of how many new trees would have to mature every year to sequester the emitted CO_2 in that period?