The very first question is what problem are we trying to solve?

Is it local air quality?

or

Is it impact on Global Warming?

or

Is it best economic performance?

CO_2 is such a great concern because it accumulates in the atmosphere

What is aviation's absolute contribution to the CO_2 problem?

- How much air is there in the atmosphere?
  – About 5200 tera tonnes (5.2*10^15 tonnes)
- How much CO_2 is there in the atmosphere today?
  – About 3 tera tonnes
- How much extra will aviation add this year?
  – About 0.0007 tera tonnes
  – An increase of 0.023%

The CO_2 lake

- In every cubic metre of this room, there are 1 million ccs of air.
- In every cubic metre of this room, there are about 375 ccs of CO_2
- This is equivalent to a pint glass 2/3 full for each cubic metre

How quickly is the lake growing?

- This year aviation will consume about 220 million tonnes of kerosene
- The (optimistic) forecast for future growth in air transport capacity is 5% per year
- Fuel burn per aircraft decreases at about 1.5% per year as new technology aircraft enter the global fleet
- Total fuel burn could grow at 3.5% per year

Is the world being driven to destruction by evil aviation?

- By 2050 the annual fuel burn could be 1 billion tonnes of kerosene
- The amount of aviation generated CO_2 in 2050 could be 3 billion tonnes
- The total amount of CO_2 added to the lake between 2008 and 2050 could be as much as 68 billion tonnes

Therefore

- By 2050, this would be an increase of 2.4% in the size of the "CO_2 lake"
- At these rates, it would take aviation 1000 years of operation before the pint glass was full

What determines the fuel burn?

- During the flight the engines burn fuel and the total mass of the aircraft decreases

$$\dot{M} = -\dot{m}f$$

- Also in the cruise –

$$T = D \qquad Mg = L$$

- Now the overall efficiency η_0 is given by

$$\eta_0 = \frac{(D \times V_\infty)}{(\dot{m}f \times LCV)}$$

- Where LCV is the lower calorific value for the fuel

- Now if the aircraft is flying at constant Mach number and at a fixed value fraction of the maximum lift to drag ratio (constant n)

$$-\dot{M} = \frac{(Mg \times V_\infty)}{\left(LCV \times n \times \left(\eta_0 \times \left(L/D\right)\right)_{max}\right)}$$

but $V_\infty = \dfrac{dS}{dt}$ where S is the distance flown

$$-\frac{dM}{M} = \frac{g}{n \times \left(\eta_0 \times \left(L/D\right)\right)_{max} \times LCV} \cdot dS$$

- Therefore, if the total distance flown is R the fuel used is

$$\frac{(MF)_{cruise}}{MTO} = 1 - EXP\left(-\frac{(g \times R / LCV)}{\left(\eta_0 \times n \times \left(\frac{L}{D}\right)_m\right)}\right)$$

- For simplicity let

$$X = \frac{g \times R}{LCV \times n \times \left(\eta_0 \times \left(L/D\right)\right)_{\max}}$$

- And, if the additional fuel used for climb is

$$\frac{\Delta mf_{climb}}{M_{TO}} = 1 - k$$

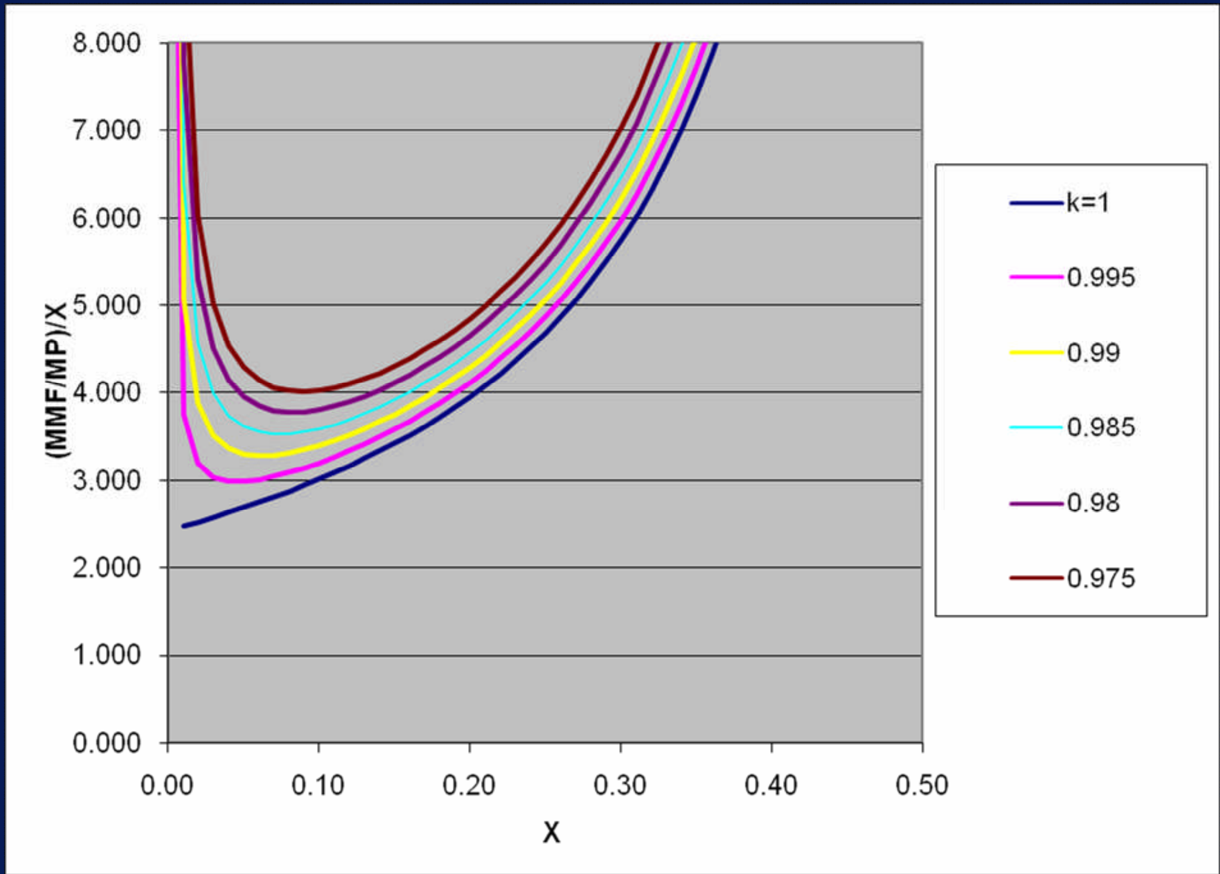
- Then

$$\frac{MMF}{MTO} = 1 - kEXP(-X)$$

- However, the usual economic parameter is

$$\frac{MMF}{(MP \times X)}$$

Sensitivity of MMF/(MP*X) to k



Sensitivity of MMF/(MP*X) to MOE/MMTO