# Let us speak "*Green House Gas*"

***A little history***

In 1971 G. Eldin, General Secretary of the OECD published a paper[1] in which he highlights how economic growth generates a series of undesirable natural phenomena such as degradation of the biosphere, pollution of air and water as well as nuisances imposed on local communities. Eldin pointed out the need to solve environmental problems at a global and not regional scale, highlighting the fact that the ecological degradation of the biosphere does not sit well with…political boundaries. 25 years before the Kyoto protocol, he also describes with surprising vision, how the potential climate changes related to $CO_2$ emission would be a huge challenge for the future generations, mentioning that doubling $CO_2$ emissions during the period 1970-2000 could lead to an increase 2°C in the Earth's temperature. 1971 also corresponds to the birth of the most famous environment-focused NGOs: Greenpeace and the World Wide Fund for nature.

In 1972, the Club of Rome[2] ordered the famous controversial study "*The Limits to Growth*"[3] from the Massachusetts Institute of Technology. Exploring a number of possible scenarios, the report stressed the contradiction of unlimited and unrestrained economic growth in a world of finite resources. It describes how the decreasing availability of fossil energy would induce a sudden collapse of economic growth, resulting in a significant reduction in the world population and a degradation of living conditions and food quota for those who remain. Beyond its content and even though strongly criticized for its provocative and quite pessimistic scenarios, "*The Limits to Growth*" raised long-term awareness among world leaders and decision-makers regarding the delicate interaction between human economic development and the fragility of the planet. It contributed to the establishment of Ministries of the Environment in numerous countries.

It is also at the beginning of the 1970s that N. Georgescu-Roegen[4] demonstrated by using the 2$^{nd}$ principle of thermodynamics, how growth was a highly dissipative phenomenon degrading the biosphere by irreversibly transforming a low entropy finite stock (oil, gas, coal) into high entropy wastes ($CO_2$).

Although the first real concern of the scientific community about Green House Gas emissions and potential consequences on climate change emerged during the 1979 World Conference in Geneva, it was only 13 years later (at the Rio summit in 1992) that the United Nations have adopted a convention recognizing the need to stabilize GHG emissions but differentiating however the responsibilities between OECD and emerging countries.

A further step was made in Kyoto (1997) where a protocol with quantitative objectives (5% reduction of emissions with respect to 1990 for the period 2008-2012) and the basis of exchange principles and rates for $CO_2$ equivalent were adopted. These rules have been applied since 2005 in the 128 countries that ratified the Kyoto protocol.

Global warming has become today a major global challenge, which could increase food and water insecurity for millions of people and cause trillions of dollars' worth of damage to the world economy.

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[1] G. Eldin (Options Méditerranéennes - 9 - Oct. 1971) « Prise de conscience des problèmes de l'environnement à l'échelon international » http://ressources.ciheam.org/om/pdf/r09/CI010438.pdf

[2] http://www.clubofrome.org/

[3] Meadows D& D and J. Randers (1972) "Limits to Growth" Chelsea green Publishing Company, White River Jonction, Vermont

[4] N Georgescu-Roegen N. (1971), The Entropy Law and the Economic Process. Traduction du chapitre 1 en français dans La décroissance - Entropie - Écologie - Économie, éd. 2006, ch. I, p.63-84

***What are Green House Gases?***

Some of the sun's incident rays traveling to Earth pass through the atmosphere, while others are reflected directly back into space. Heated by the incident rays, the Earth's surface radiates the heat into space essentially in the infrared spectrum. Nonetheless, only part of this radiation passes through the atmosphere. Greenhouse gases (water vapor[5], carbon dioxide, methane, nitrogen dioxide) that naturally occur in the atmosphere in very low quantities absorb the other part and sends it back to the Earth, keeping its surface at a higher temperature than it would be if the GHG weren't there (**Figure 1)**. Yet without GHG, life could not exist on Earth.

However, not all greenhouse gases have the same Gas Warming Power (GWP). The latter is the integral of its "instant radiative forcing" $F_g(t)$ which depends on its spectrum of adsorption over the time it remains in the atmosphere $T$:

$$GWP = \int_0^T F_g(t)\,dt$$

**Figure 1** compares the radiative forcing graphs for $CO_2$ and $CH_4$ which show that although methane has a higher instant radiative power, its lifespan in the atmosphere is much shorter (12 years compared to nearly 100 years for $CO_2$).

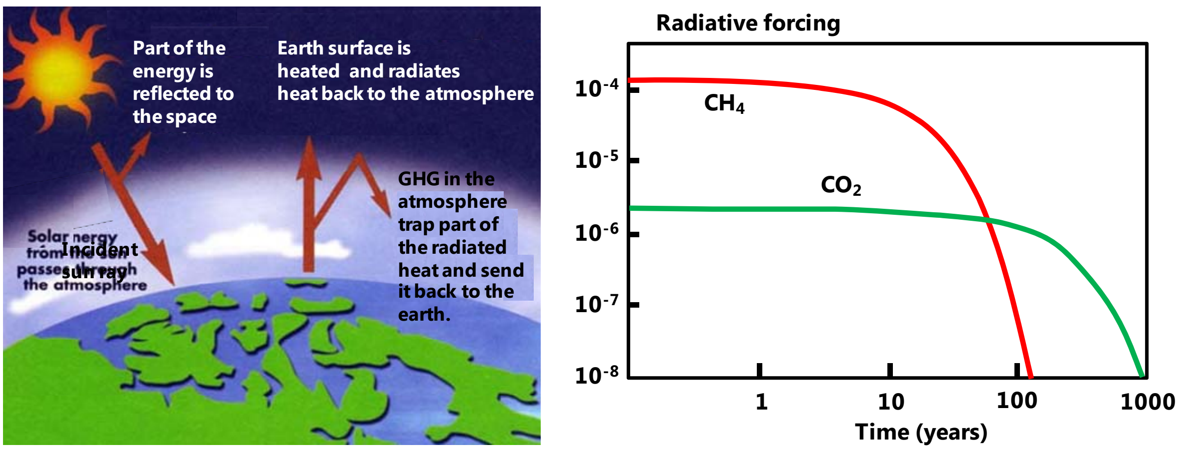


**Figure 1 – Greenhouse gas physics. Radiative forcing and lifetime of $CO_2$ and $CH_4$. In spite of a much shorter lifespan, the radiative forcing of methane is much higher than that of $CO_2$. Methane has a GWP 25 times higher than that of carbon dioxide**

For this reason it is preferable to calculate, over a period of *T=100 years*, a relative gas warming power such that:

$$GWP = \frac{\int_0^T F_g(t)\,dt}{\int_0^T F_{CO_2}(t)\,dt}$$

So the relative *GWP* of methane is 25 which means a quantity of methane present in the atmosphere for a century will have an effect 25 times greater than that of $CO_2$. Certain GHG present in very low quantities in the atmosphere have a very high GWP (298 for nitrogen oxide, 22,800 for sulfur hexafluoride - **Figure 2**).

[5] The atmosphere is mainly made of Nitrogen and Oxygen which are not GHG. GHG represent only a small fraction of the atmosphere. An increase in GHG content in the atmosphere does not generate pollution and does not have any direct impact on health on a global scale.

| Gas | Chemical formula | Life span (years) | GWP (100 yrs) |
|---|---|---|---|
| Carbone dioxyde | $CO_2$ | 30–95 | 1 |
| Methane | $CH_4$ | 12 | 25 |
| Nitogen protoxyde | $N_2O$ | 120 | 298 |
| Sulfur hexaflurorure | $SF_6$ | 3200 | 22800 |

**Figure 2 –Gas warming power (GWP) of certain greenhouse gases in the atmosphere**

***Increase in GHG owing to human activity***

Although GHG are crucial to life on Earth, any excess in the atmosphere increases the temperature at the surface of the planet, which then impacts the climate. It has now been established that the use of fossil fuels (coal, oil, gas) since the industrial revolution has been one of the main contributors to the increase of $CO_2$ in the atmosphere. The regular measurements taken as of 1958 by Charles David Keeling led to the famous "Keeling Curve" or "Mauna Loa" curve after the name of the Hawaiian resort in which the measurements were taken. In the space of 50 years, the average concentration of $CO_2$ in the atmosphere therefore increased by 20%, from 320 ppm[6] in 1958 to 390 ppm in 2010 (**Figure 3**).

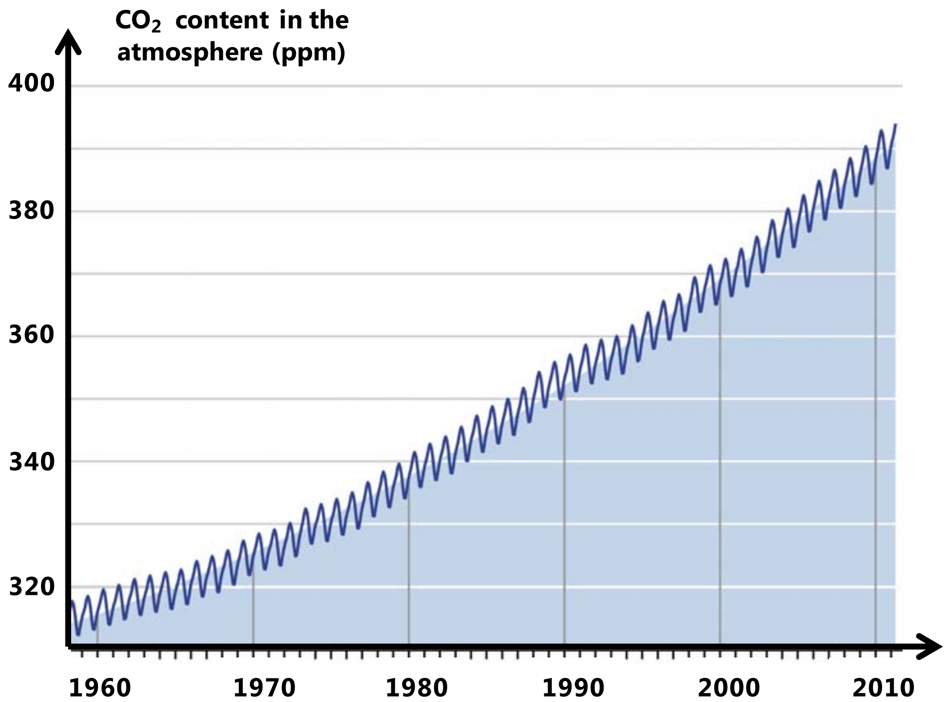


**Figure 3 – The Keeling Curve (http://www.climatepedia.org/Keeling-Curve)**

[6] ppm = parts per million

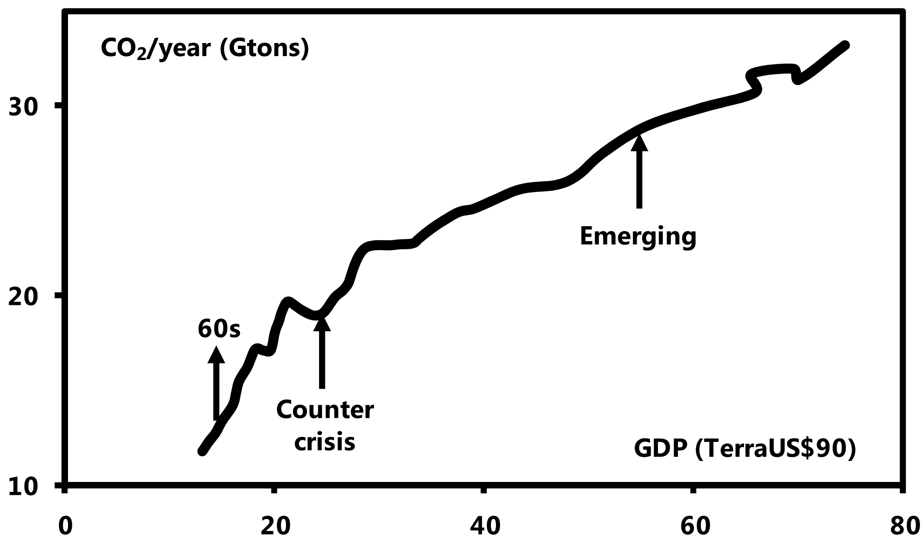


**Figure 4 - Relation between the production of GHG and world GDP between 1965 and 2010**

Regarding emissions, not all fuels are equal. For an equivalent energy content, the emissivity of coal is 75% higher than that of natural gas, which appears to be far and away the most ecological fuel (**Figure 5**).

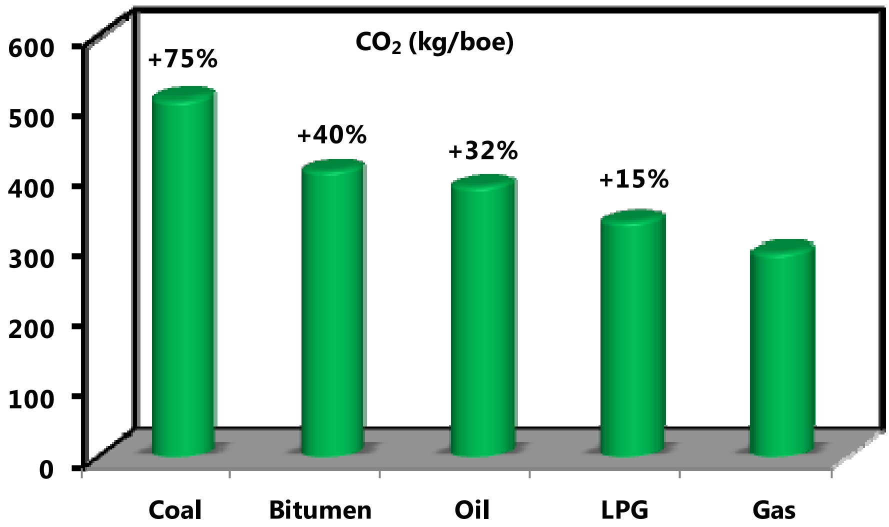


**Figure 5 –$CO_2$ emissions by fuel type**

To highlight the impact of demographic and economic growth, let's break down emissions as follows[7]:

$$CO_2 = \frac{CO_2}{boe} * \frac{boe}{GDP} * \frac{GDP}{INHAB} * INHAB$$

On the right-hand side (1) is the emissivity of a given fuel, (2) the energy intensity, (3) the GDP/inhabitant and (4) the world population. Therefore, demographic and economic growth are not conducive to stabilizing or reducing the quantity of emissions unless the energy intensity is reduced or

[7] http://manicore.com/documentation/serre/kaya.html

if high-potential fuels (coal) are progressively replaced by lower-power fuels (gas) or those with none at all (nuclear or renewable).