Michel de Rougemont
Enterprise Consulting

Widhagweg 10
CH-4303 Kaiseraugst
Switzerland
Phone +41 61 813 9175
Mobile +41 79 705 4811
contact@mr-int.ch
www.mr-int.ch
blog.mr-int.ch

Michel de Rougemont, September 3rd, 2016

In defence of carbon

Important disclaimer: this text was written without any financial support or endorsement.

Carbon (C) is in the centre of all praise and criticism, up to the point of naming pollutant one of the most vital molecules, carbon dioxide, CO_2.

Approximately 86% of all energy consumed in the World stem from the combustion of fossil fuels that produce CO_2 in stoichiometric amounts.

Without energy, no human development would take place.

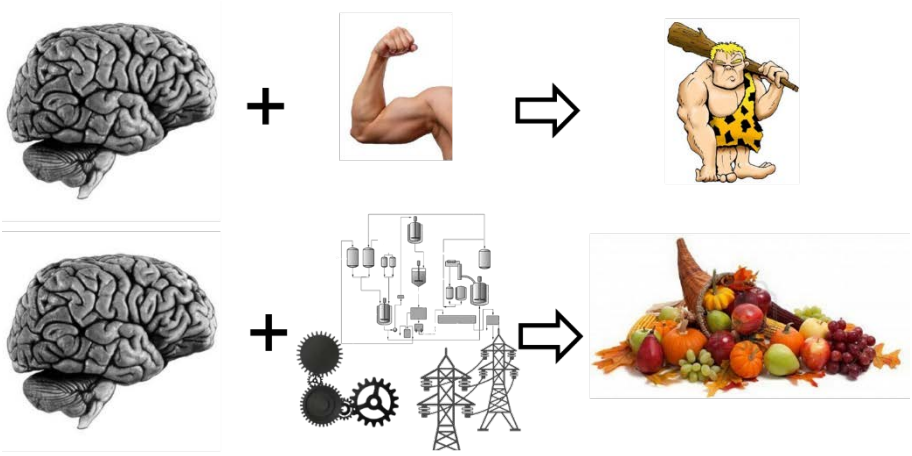


Figure 1 The road to prosperity

Ones can consider this use a pilfering of resources; others will salute the many astute ways of unleashing our creativity and our innovation potential to improve our living conditions.

Two questions arise:

1. What is the worth of the carbon that we consume and emit to the atmosphere in the form of CO_2?
2. What are the damage and losses associated with such use?

As bean counters are no more limiting their playground to coins and other virtual currencies, statistics are available in the form of time series of value created, and of carbon consumed[1].

[1] The GDP data from the World Bank date from 1960. All GDP data are taken at constant 2005 US$ value. Carbon emissions compilation by CDIAC dates from 1750 to 2013.

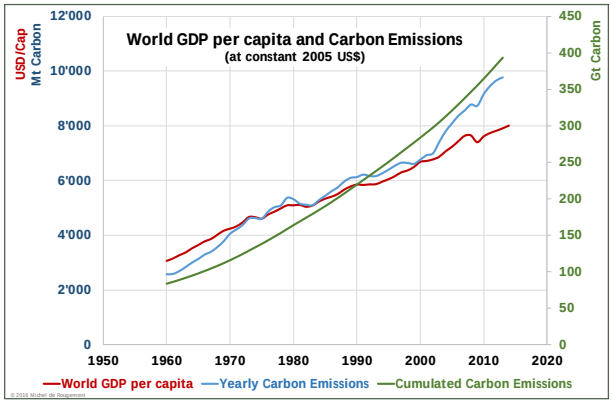
The value creation is the sum of the gross domestic products of all countries, making the World GDP. It can be divided by the population number to estimate the value created by an improbable average individual, also known as GDP per capita.

Of course, this does not include non-material values such as comfort, safety, or pleasure. Neither does it take into account negative aspects, fears, despair, and other ills. Notwithstanding the impossibility to agree on value levels and on amounts of such qualitative factors, one can use economic parameters as proxy for the measurement of our well-being. This means that an answer may be given, at least partly, to the first question.

However, no valid assessment can be made to answer the second question. If it is straightforward to measure damages and losses of physical assets, estimated at their replacement value, damages on general life conditions or on the environment will depend on the value scale that will be chosen. And no consensus can be achieved on such scale. Also, opinion polls or forceful rants cannot be added together into useful measuring parameters.

Any consumption of energy will help produce, hopefully, useful products and services; but it will also be associated with so-called externalities which can be negative or positive. Some are quite obvious, for example: road transport will wear and tear roads, or increased CO_2 concentration accelerates plant growth. Externalities' costs and benefits are sometime easy to attribute; but in most cases the multiplicity of causes and their relative attributions present an impossible conundrum, leading to biased statistics and fruitless debates (but so "interesting").

So we have to stick with GDP, as evaluated by national accounts, and with carbon uses as compiled by statisticians.[2]



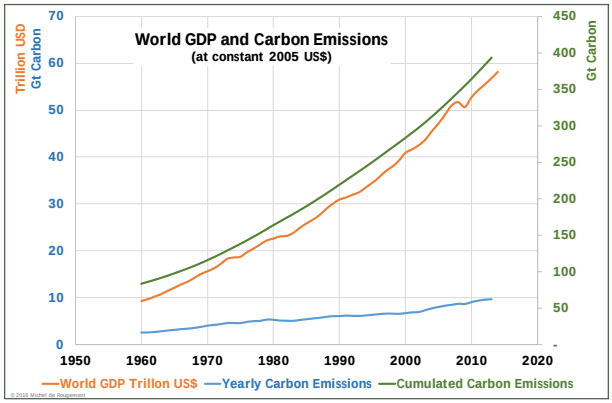


Figure 2 and Figure 3 Growth of GDP (red) per capita (left) or total (right), and carbon emissions on a yearly basis (blue) and cumulated since the beginning of the industrial era (green).

The steady economic growth of the past half-century was accompanied by increased carbon related emissions.

---

[2] Playing with billions and trillions (an American handicap):
Billion is bn or G for giga (10^9), Trillion is tn or T for tera (10^{12}), and P for peta (10^{15})
One Tg is one teragram or one million metric ton, Mt.
One Pg is one petagram or one billion metric ton, or one gigaton, Gt
The molecular ratio CO_2/Carbon is 3.66. By burning one ton equivalent of carbon, 3.66 ton of CO_2 will be produced.

Since the beginning of the industrial era, at the end of the 18th century, a total of 83.4 Gt C was emitted up to 1960. In 2013 this total had accumulated to 393.6 Gt C, a multiplication by 4.7.

Current emissions run at a rate of 9.8 Gt C per year, increasing each year by 1-2%.

On a per capita basis the economic growth rate was not as steep as the emissions; this can also be seen on the following graph.

These time series don't offer yet an indicator of carbon value. A ratio can be calculated between GDP produced and carbon consumed; it will be an indicator of carbon efficacy, expressing how much worth was created by consuming one unit of carbon.

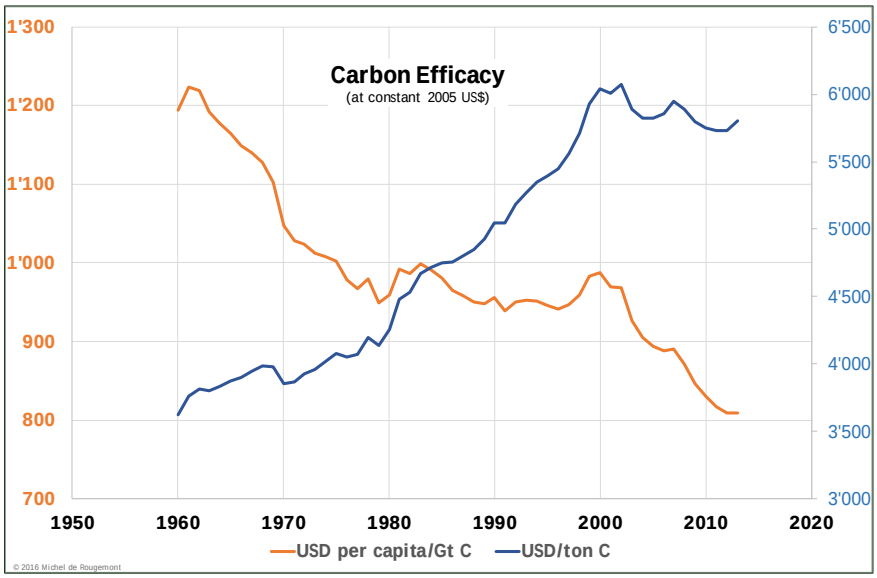


Figure 4 Carbon efficacy: how much GDP results from the consumption of one unit of carbon.
In other words, between 1960 and 2013 the World GDP created by emitting one metric ton of carbon has increased from 3'600 to 5'800 US$, a 61% increase.
But the GDP per capita created by one gigaton of emitted carbon decreased from 1200 to 800 US$ per person, a 33% decrease.

During this period, the World population grew from 3'034'970'564 to 7'174'521'359 (one will appreciate the World Bank's accuracy, never mind), a 136% increase. Thus carbon efficacy has improved at a faster pace than demographic growth, an unexpected result for Malthusians.

Nevertheless, instruments were put in place by the state to decrease CO_2 emissions, as for example carbon certificates. On August 31, 2016 the certificate for European Emission Allowances is valued at 4.43 EUR (4.93 USD) per ton of CO_2. Also a carbon tax of 84 Swiss francs (83 US$) per ton of CO_2 represents only a tiny fraction (0.51%) of its contribution to GDP, that was 16'350 CHF/ton CO_2 in 2014. It is quite improbable that such minute amounts may have any overall economic impact on the use of fossil fuels. It is also unimaginable to pretend setting such taxes at very high levels without attributing an excessive planning power to national governments. Or, it may well be that this is the underlying motivation of the proponents of heavy carbon taxes.

Note that Switzerland[3] is ranked 184th out of 193 UN member states for its CO_2 emissions in relation to its GDP (CO_2/GDP, the inverse of Figure 4). This is an example showing that progress means also high efficacy in the use of scarce resources; and this will be done with technology rather than by proclaiming restrictive measures.

GDP growth is extremely well correlated with the quantity of carbon emitted, which is unsurprising for any reader willing to understand Figure 1 that explains such direct causality.

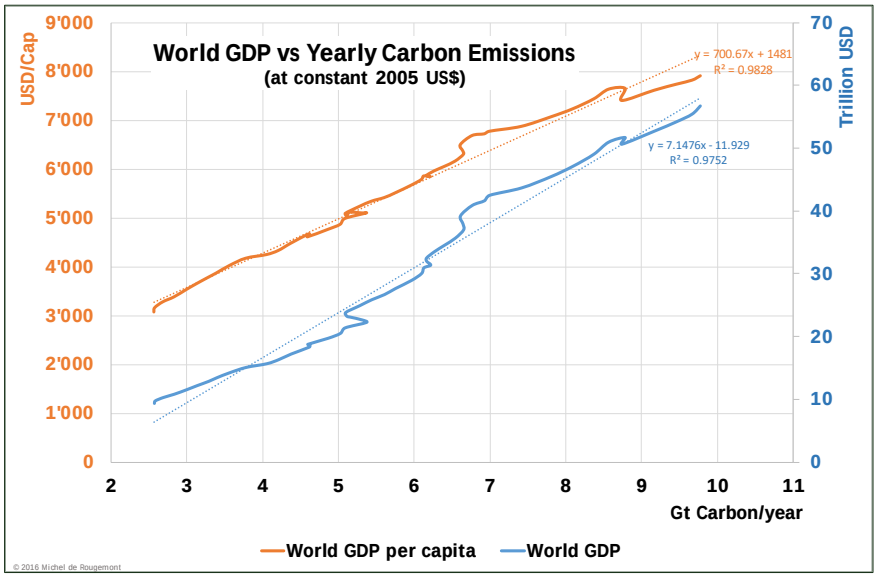


Figure 5 GDP in relation with yearly carbon emissions
With a probability of ~98% the correlations indicate that for each additional ton of carbon emitted each year, the Word GDP increased by 7147.6 US$. Or for each additional gigaton of carbon emitted each year, every person generated 700 US$ additional wealth.

Another view, with historical perspective:

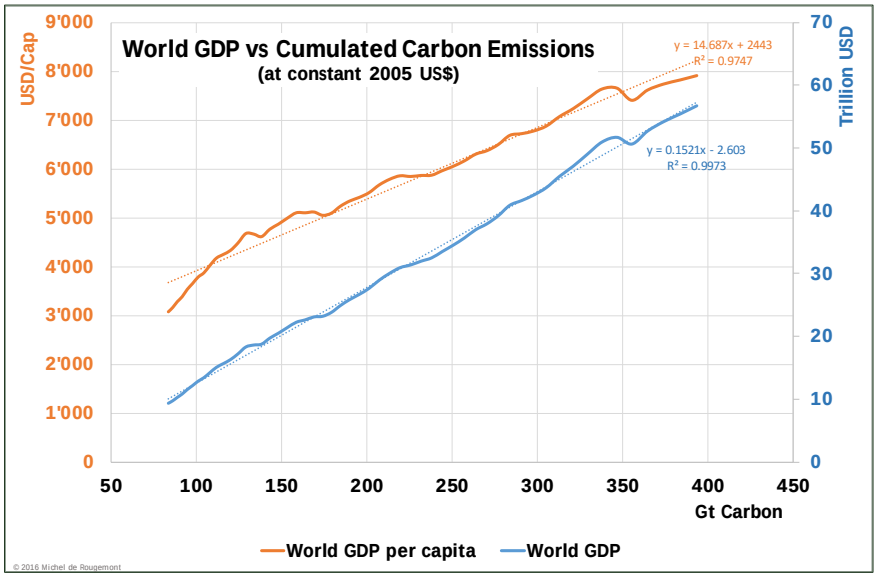


Figure 6 Wealth creation by accumulation of carbon emissions.
Read as: each ton of carbon emitted since the beginning of the industrial era (BIE) contributed to build up the yearly World GDP by an additional 152 US$.
Or in other terms, each gigaton of carbon emitted since BIE contributed to build up the yearly individual wealth creation by 14.7 US$ per person.

---

[3] Contrary to general cliché, Switzerland is not just a financial heaven and chocolate maker. Its industrial sector accounts for 28% of its GDP, similar to Germany, and higher than in UK (21%), France or the USA (both at ~19%). Its financial sector contributes only to 10% of the PIB, employing 6% of the country's work forces.

From Figure 6 it can be understood that, since the beginning of the industrial era (BIE), at the end of the 18th century, human societies have accumulated all know how that produce our today's well-being; and all carbon consumed so far (393 petagram C) contributed to a given year's GDP by 152 US$ per ton.

Pushing further the cumulated views reveals two even more striking correlations, with a r^2 coefficient higher than 99%:

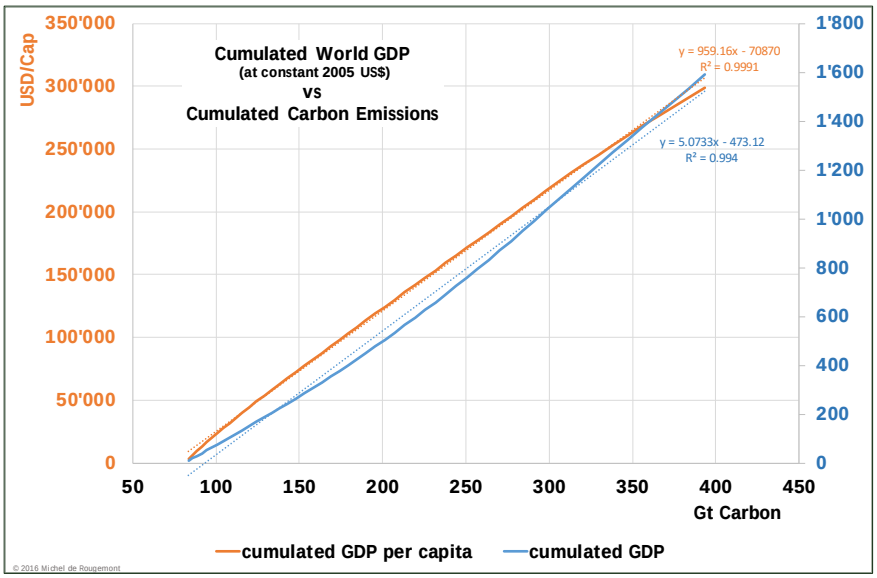


Figure 7 Cumulated contribution of carbon (since BIE) to wealth creation (since 1960).
Read the correlation equations as: each ton of emitted carbon has generated 5073 US$ of GDP.
Or: each gigaton of emitted carbon has generated a wealth of 960 US$ per person.
Note however the significant continuous increase of the slope of the total GDP curve (blue), indicating that the current efficacy of carbon is higher than the historic value.

Large differences exist among countries, not addressed in this short presentation. Nevertheless, similar trends can be observed everywhere, with conflicts and crisis being the most important disturbing factors.

Take home points

1. Because of its essential contribution to wealth generation in all sectors of human activity, carbon is worth much more than the mere costs of extraction, refining and distribution of fossil fuels, and of corresponding pollution controls.
2. Depending on the view that is taken, an additional emission of one ton of carbon (the equivalent of 3.66 tons of CO_2) contributes to the World GDP by 5'000 or 7'150 US$ (at constant 2005 value).
3. This energy efficacy has been increasing, faster than demography, a measure of technical progress.
4. Being the driver of economic growth, any reduction attempt must be compensated by solutions that are at least as efficacious, similarly available (timeliness, storage), and affordable (economy).
5. This is not yet the case with so called renewables that, mostly in Europe, are intended to substitute nuclear generated electricity, a political decision. In addition, they have an intermittent production pattern (solar, wind) that make them poorly available as long as economic ways of storage and restitution are not developed at the required [huge] scale. Today's backup solutions are coal or gas based.
6. Current programmes and instruments to curb carbon emissions are:
   a. Futile for changing the climate change.
      The observed warming can be accurately modelled without the intervention of CO_2. Thus it's far from being proven that CO_2 is the sole culprit of global warming.
      No observational data is available to prove the hypothesis of an anthropogenic cause of climate change, even if some contribution may be plausible (radiative forcing).
      No model simulation could be validated to demonstrate the climate sensitivity on CO_2. Almost all exaggerate it, grossly in many cases.
      No climate will significantly change if less carbon will be emitted.
   b. Dangerous for our prosperity if the GDP-to-carbon economic leverage would be deteriorated for dogmatic reasons, without true solutions to ensure on-going development.
7. Developing countries need energy; and it is overwhelmingly carbon based.
   They don't need advices about not producing it in order to not use it, given by well-fed ideologues.
   When limiting growth, no social and environmental progresses can be expected.
8. The proven fossil fuel reserves are constantly adjusted upwards.
   They are now at ~40 years for oil and gas; it was deemed to be only 25 years in the 60s.
   Coal reserves can last centuries.
9. Not using wisely these reserves will serve no one.
10. True alternatives will, over time, be developed up to industrial scale.
    They cannot be ordered by decree.

The challenge for us and for the next generations is to harvest energy in various forms that will complement and eventually substitute fossil fuels in a technically feasible, and economically viable way.