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ENERGY AND ECONOMICAL GROWTH: OVERVIEW AND GLOBAL CHALLENGES

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Abstract

This paper is a global overview of the correlation between economic growth and energy consumption. It insists especially on the very important role of the oil in the 20th Century development, to point out that the future will not be so bright, because of the impact of combustion gases emissions on the greenhouse effect and because of the decreasing of the resource. The importance of "fossil" energies for different uses is shown shortly as well as the capacity of the taxes to modify some of these utilizations. Renewable energies are also examined with some of their specific difficulties to be massively developed, because of their high "manufacturing" costs. The paper evocates that the production cost of different ersatz of the fossil oil will be comparatively so high that this "oil new deal" will likely induce a new model of growth.

Key words: correlation, energy, model of growth, oil new deal

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1. Introduction

Since the first oil shock (1973), which was to sow doubt about the "actual availability" of oil resources, and with the massive awareness of environmental problems caused by its use about 15 years later, noticeable efforts have been made by engineers and scientists to improve the efficiency of fossil fuels, especially oil when it came to fuel, in order to go in the direction of the economy of the primary resource and of the corresponding reduction of atmospheric emissions (Chow et al., 2003; Field et al., 2008). At the same time there has been an ever greater enthusiasm for public exhibition of the uselessness of "heavy" symbols of a certain wealth and other social success: the advent of 4x4s and other large sedans "just for fun", the development of low-cost airlines, air conditioning and heating equipment for living spaces that became more and spacious etc., besides, with the demand for these technologies in the emerging countries on one hand and more generally the world population growing exponentially on the other hand. In short, the efforts of ones have been thwarted by the behavior of others. However, the development of this world of material wellbeing still today lies upon the paradigm of easy energy (fossil), unmindful of its environmental impact (Armaroli and Balzani, 2006; Hall and Klittgaard, 2006).

The analysis which follows aims at presenting an overview at the same time overall and very quick, as it may appear at the intersection of paths follow by the physicists/engineers in mechanics and thermodynamics who are mainly concerned with the transformations of energy, with those of analysts in energy resources and also with those of economists: and this, without forgetting a more radical "green" view.

2. The global energy problem: evolution and current status

With his knowledge on the practice of fire, energy was "presented" to man initially in the form of wood, animal fats, and mineral fuels in solid (coal) and liquid (oil) and finally in gaseous form (natural gas). The presence of large deposits, an apparent abundance, and a relative ease of use have made the fossil fuel the foundation of economic growth in the nineteenth and especially the extraordinary one that will characterize the second half of the twentieth century (Holdren, 1991; Walker, 2007).

Table 1. The place of fossil fuels in the world between 1980 and 2006 (AER, 2010)

"Fuel" type (%)	*1980*	*2004*	*2006*
Oil	46.6	37.6	36.5
Gas	19.2	23.2	23.0
Coal	24.9	26.0	27.2
Total of "fossils"	**90.7**	**86.8**	**86.7**
Hydroelectric	6.4	6.2	6.4
Nuclear Power	2.7	6.1	5.9
Other renewables*	0.2	0.9	1,0

**wood not included (about 10% of the total "fuel")*

As a corollary, the desire to optimize the use of each of these forms of fossil fuels has led to innovations and other technological advances often brilliant (steam-engines, heat engines), some of which have been boosted by the major conflicts experienced by the twentieth century . When global energy is evocated today it is still speaking primarily of fossil fuels, while other forms of primary energy remain low, even subjective when only the "other renewables" are considered (Table 1) (Chow et al., 2003; Gavrilescu D., 2008; Gavrilescu M., 2008; Mundaca and Plepys, 2007).

One of the main purposes of this paper is to emphasize the almost perfect correlation between growth in gross domestic product (GDP), energy (essentially fossil fuel) and greenhouse gases emissions (GHG) - as is exemplified by OECD case in Fig. 1 (ESM, 2010; Rühl, 2010; Rühl and Giljum, 2010). Here, it can be identified the temporary decreases of the three indicators in the wake of the three oil shocks (1973, 1979, 2000). It should remember that, for an extra point of economic growth, one consumes about 0.5 points more primary energy, while the emissions of greenhouse gases (CO_2, methane, water, NO_x, CO, ozone, fluorinated gases) exhibit an increase of 0.3 points.

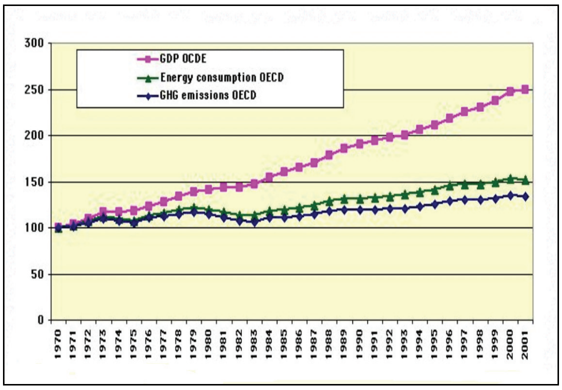

Fig. 1. GDP / Energy consumption / GHG emissions in OECD (http://www.manicore.com/anglais/ documentation _a/greenhouse/growth.html)

These correlations being noticed, it is enough to look at the evolution of one of these data to know the others (Guillet, 2002). So the focus was chosen on the "black" slope of the extraordinary economic growth that can be seen by following for a longer period the evolution of atmospheric CO_2, the first and easiest to measure GHG (it is estimated that CO_2 alone is responsible for 55% to 60% of the greenhouse effect due to human activity) (Dinca et al., 2009; Herzog and Golomb, 2004; Robinson et al., 2007).

Fig. 2 shows clearly linear evolution of CO_2 concentration in the atmosphere to the end of the 50s, followed by an exponential curve up to now (Etheridge et al., 1996; Barnola et al., 1995; Stewart, 2009; http://blog.hofer.us/wp-content/uploads/2008/ 08/gw2.gif).

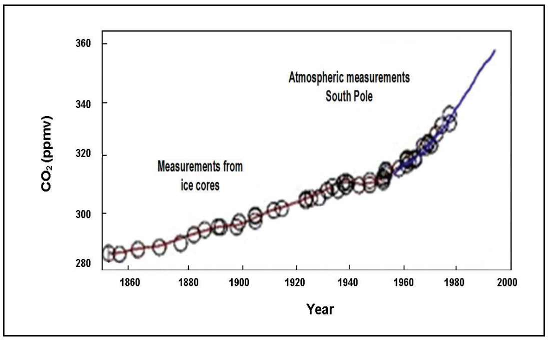

Fig. 2. Evolution of atmospheric CO_2 since 1850 (according to Etheridge et al., 1996; Barnola et al., 1995; Stewart, 2009; http://blog.hofer.us/wp-content/uploads/ 2008/08/gw2.gif)

3. The use of fossil fuels in the world

A closer look shows that in fact about 95% of the fossil energy-bearing material is transformed into energy (Table 2), the rest having also a very important role in the growth and economic development as it constitutes the basis of the diversified and often high added value petrochemical processing industry: plastics, composites and other derivatives of the polymerization of naphtha from crude oil, (even the bituminous coating of our roads) (Walker, 2007). But among the different forms taken by fossil fuels, oil is currently undeniably the most sought after for its liquid form, its stability in normal atmospheric conditions of pressure and temperature, for its energy density (energy per unit of mass and/or volume), and for its "shelf life" or the ability to store on board the fuel. Oil is the primary energy source for land, sea and above all air transport, covering up to 95% of the energy needs of global transportation (this also corresponds to 52% of the total oil consumption and 23% of the total world energy consumption) (Farret and Godoy Simões, 2006; Herzog and Colomb, 2004; Nakićenović et al., 1998).

Table 2. The use of oil in the world (http://globalenergyobservatory.org; http://ec.europa.eu/energy/energy_policy/doc/factsheets/mix/mix_fr_en.pdf)

Terrestrial transport	***Industry***	***Power Refining***	***Residential Tertiary***
41%	16%	15%	9%
Air transport	***Sea transport***	***Non-energy applications***	***Agriculture***
6%	5%	5%	3%

4. Status of fossil energy reserves

Fossil energy is not renewed (at least at human being time scale), because it is a stock (Table 3), considered as a boon granted by nature, which has been spent and continue to be without care (Moriarty and Honnery, 2009; Shafiee and Topal, 2009). But any tank has a bottom, the stock runs out today and some people have become anxious to know when the "sinks" will dry up, when the operation of the "well" will kick off its decline, the moment of peak - oil. While the issue has been debated among experts, all of them believe that all children born today will live this time at adulthood, then the shortage and all that can induce stress of different kinds, including geopolitical. So basically, the peak - oil in 15 years or 30 years does not change the problem for our generation and even less for the following. However, from author's point of view, the ecological constraints must "reasonably" be considered the strongest and must compel people now to a change course that must particularly affect the appetite for fossil fuels including oil and therefore before the peak – oil or other peak - gas and peak - coal announced for later.

Table 3. Reserves of fossil fuels (http://ec.europa.eu/energy/energy_policy/doc/factsheets/mix/mix_fr_en.pdf)

Type of resource	***Gtoe in proven resources***	***Years of constant consumption (reference:2005*)***
Coal and lignite	460	160
Oil	160	43
Unconventional oil**	80	-
Natural gas	160	65
Total	**860**	**95**

**Consumption was about 9 Gtoe fossil energy in 2005*
***E.g. oil shale and other natural bitumens*

The "top" of the ultimate range of global reserves of fossil fuels accounted for in late 2005 of about 4000 Gtoe divided in 800/900 Gtoe of "proven" reserves, and approximately 3,000 Gtoe called "additional reserves" (the last ones are extractable fraction of all the hydrocarbons in the reservoirs to confirm, and in reservoirs already discovered and to be put into operation when the technology has progressed and will become "profitable") (Hirsch, 2005; Houghton, 2004).

5. About other planetary "heritage" energy sources

5.1. Nuclear power

One seldom speaks of uranium reserves: 100 years or 1000 years? According to the French Society of Nuclear Energy "… used in current reactors, the uranium resource is, in imitation of the today oil resources appreciation, at the time scale of the century. However, thanks to fast neutron reactors, it could meet our needs across several millennia. Here no GHGs, but the potential dangers associated with nuclear power cannot be ignored - one thinks of the accidents and the issue of waste management in the long term" (http://www.sfen.org/home2.htm).

5.2. Methane hydrates

Methane hydrates (it is 6-7 water molecules that, under certain conditions of temperature and pressure, can trap a molecule of methane) are less known (Kim et al., 1987; Kvenvolden, 1988). However, already around 2000 it was being told at the *California Scripps Institute of Oceanography* (http://www.sio.ucsd.edu/) that there were 3000 years of reserves of methane hydrates in deep sub - marine resources). From author's point of view and if it should be, this form of energy should be preferably exploited (converted to electricity) *in situ*.

6. Renewables

Today the renewable energy represent 1% (about 7% when hydraulic is considered), but in the future it should cover all the energy needs! (Twidell and Weir, 2006). Moreover, apart from the residential hot water and space heating (through solar panels, heat pumps, and geothermal), these renewable energies will be primarily for electricity generation, an electricity very costly! (Table 4) (Armaroli and Balzani, 2006; Chow et al., 2003; Mundaca and Plepys A., 2007; Tita and Calarasu, 2009; Vizureanu et al., 2009). And the above costs do not include externalities or indirect costs such nuisances! But they are interesting for comparative values. The ranges of costs are often very very large due to the variety of sites, and infrastructure costs (construction and operation).

6.1. Hydropower

The best sites for traditional hydropower (dams) are now in use (at least in the West).

Among the major new unknowns to consider now, the uncertainty of climatic changes and their impact on hydrology and the ability to obtain acceptance (by democratic means!) for the destruction of natural sites will be discussed.

Table 4. Comparison of production costs of electricity from "primary" energy sources (Guillet, 2010b)

Energy source	*Costs * In 1995/2000 (OT**)*	*Costs related to RL****	*Costs related to RP*****
Hydraulic	2 -10 (2=RL)	RL	2.86 x RP
Photovoltaic	25 - 125	12.5 x RL	35.7 x RP
Wind-Tide	5 - 13	2.5 x RL	3.7 x RP
Biomass	5 - 15	2.5 x RL	4.3 x RP
Coal	3.7 - 4	1.85 x RL	1.14 x RP
Gas (combined cycles)	3.3 - 4.3	1.65 x RL	1.23 x RP
Nuclear	3.2 - 3.5 (3.5=RP)	1.6 x RL	RP

unit : one hundred € / kWh; **OT = out of taxes; * RL = the lowest of "ranges lows (in the above Table RL=2)*
*****RP = the lowest value of "ranges peaks" (in the above Table RP=3.5)*

For example, in France, all that remains is the micro hydro or turbines over water. But again there are voices warning about the consequences on the surrounding environment.

6.2. Photovoltaic

This technique of producing electricity is 12-36 times more expensive than conventional hydraulic or nuclear. It requires a large footprint and may be in conflict with farming. As often with renewable energy electricity production is discontinuous, even random, and the application of photovoltaic poses the problem of storing the energy produced. Now, high expectations are based on the technology of lithium batteries and through this, photovoltaic and electric cars have linked destinies, but with the risk that their development is hampered by the relative rarity of lithium.

6.3. Wind and tide

In this case, the production of electricity is 2.5 to 3.7 times more expensive than hydropower or nuclear (Jacobson, 2009). Furthermore, people begin to understand the noise pollution onshore wind turbines. In the case of submerged tide or stream technology, it is likely that local marine ecosystems are disrupted. So, the two technologies are already highly controversial (Meisen and Loiseau, 2009).

6.4. Biomass

Even if wood is not the only "biomass" resource, trees and forests are the first representation, with a double challenge. Indeed, source of energy (and materials), trees are the "terrestrial carbon dioxide sinks", the most important after the oceans (Lako et al., 2008; Fischer et al., 2007; Gavrilescu M., 2008). It is important to remember that a felled mature tree will be replaced in terms of its photosynthetic capacity and absorption of CO2 after several decades (Gavrilescu D., 2008; Popa, 2008). And this remark is of utmost importance when it is told that there are no more than 15 years to respond and limit global warming to some degree (there is little specific about the number!). So, the reasonable supposition might be that, since today, there must be a global moratorium of at least 15 years on deforestation activities.

6.5. Biofuels

Biofuels are also expensive to produce. To launch them (make them more competitive), many states are ready to de-tax them (see further development on taxes, and then it will be possible to launch some idea of the average cost of production compared to fossil fuel!). Moreover, strictly referring to energy, the carbon balance of "Operation biofuel" is very controversial in many parts of the world! Thus, after the cereals pathway and its impact on the food issue, after the 'jatropha' pathway, which is more acceptable as it plants in semiarid regions, then the (micro) algae and the "algocarburant" opens already the third generation of biofuel (Chisti, 2007a, b; Gavrilescu M., 2008; Mateescu et al., 2008). In reality, for its use as fuel, the pathways that substitute oil remain all problematic, and the geostrategic issue here is considerable when it is know what the Western economic development of the twentieth century owes to oil and to its use as fuel (Demirbas, 2007; De Santi, 2008).

7. The issue of taxes on fuel and emissions

Traditionally, the fuel business is invaluable to governments who find in this significant budget revenue and a strategic lever to support or otherwise compel particular activities (Rietveld and van Woudenberg, 2005; Sterner, 2007). Globally, taxes on fuel (Table 5), on their "effect" (carbon, border taxes and similar or others) may upset the deal of "free trade", which therefore explains (in part) the timidity with which the latter are "activated" (Davoust, 2008).

Exceptions

Meanwhile, the world is still respecting the Chicogo Convention (a just after the Second World War decision) which, to develop the air transport, has banned the kerosene tax (provision to think about when it is known that the consumption of aircraft per kg transported is 10 times that of the train!) (Helms and Lambrecht, 2006).

Table 5. A short worldwide comparaison of the fuel taxes retated to the final price (early in 2008 for “95, no plumbed benzolene”) (Davoust, 2008)

Country	*Taxes / Final price (%)*	*Country*	*Taxes / Final price (%)*
Great Britain	63	Poland	57
Germany	63	Ireland	55
Holland	62	Hungary	53
Norway	61	Spain	50
France	61	New Zealand	40
Turkey	59	Canada	28
Italy	58	United States	16

Other sectors are also affected by economic, partial tax exemptions: this is for example in France, the case of fishing, agriculture, taxi transport (Barde, 2004; OECD, 2008). It is also used the “tax rebate” to start the development of a particular production chain of oil substitutes.

8. And now, what are we going (need to) to do?

The transition from an economy based on easy energy (fossil), virtually free to “produce”, to an economy based on manufactured energy, renewable or not, but still very expensive to manufacture, will radically change the economy challenge to the point that the new context “energy” alone will bring the world to live implicitly an alternative model of development (Guillet, 2004; Guillet, 2009; Guillet, 2010a, b; Lazaroiu et al., 2008), more inclined to highlight the virtues of proximity between production and consumption, more likely (hopefully!) more inclined to induce other economical choices, more attentive to their human consequences, and - why not - more inclined to a “fair” share of “new wealth”.

Ultimately, the question that now seems to be the most relevant are the modalities of "shifting" from the current model to the model to come. The latter having to incorporate the scarcity where there was abundance, so much more efficient in energy, water, available space, and having to meet radically new challenges (Guillet, 2009).

9. Conclusion

The unmindful use of fossil energy from the natural heritage has allowed the West to achieve a never reached economic development. And the existence of this manna itself boosted often remarkable technological advances.

But the twentieth century could not go to completion without revealing long time unsuspected limits and willfully ignored: those imposed to us (already!) by environmental disasters whose terms are consistently superlative, those of natural resources becoming scarce and ultimately causing irreversible disorders and many other conflicts in a context of scarcity.

At the dawn of this new century, everything seems undetermined and the “model” (unfortunately!) that still dictates our collective and individual choice has no real substitute. So we can assume that the “easy” energy resource dried up, the inevitable use of “manufactured” energy necessarily bring with it a new model of “development” that will no longer allow certain “excesses” of the recent past.

Let’s make this new model of development be not necessarily accompanied by too much pain for the greatest number!

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