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life on earth, the long term

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In a few centuries from now historians will talk of the pre-fossil fuels era that ended with the 18th century, of the post-fossil fuels era they shall be living in at the time, and of a few in- between centuries that may be called "the fossil fuels era", that we live in today and that shall remain most significant for having brought significant changes to life on Earth, and not for the best.

prologue

Recent interest in global warning was brought about by the visibility of some of its consequences. This came together with a profusion of other, maybe less visible changes to the conditions of life on Earth that were the result of things, most having taken place over past centuries, the *long term.* But what we see, what information is reported by the media belongs to the *short term,* decades or less. What corrective actions are proposed, what we can do are also limited to the *short term,* dealing with the symptoms only of a more profound disease. Having participated since the 1950's' and in different capacities to the story, I felt like having to do something that was missing, analyzing the situation as seen from the *long term* perspective. This includes taking into account information coming with our experience of the past, information lost to the many analyses of the situation limited to the short term perspective.
All that follows is based on recent published data, proper to the entire world, all conclusions are to be considered as no more than an interpretation of what that data says.

our changing world

Today's life on Earth is in the middle of a period of significant change, change that started with the discovery, often illustrated by James Watt's steam engine (1795), that energy in the form of mechanical power could be derived from thermal energy that could be obtained by burning wood or coal at first, oil and natural gas later on, those at the time other than wood referred to as fossil fuels. Before that and other than for windmills, watermills and the like, the only available sources of mechanical power were muscular, from humans or animals. It turned out that the amount of power available from fossil fuels was by orders of magnitude greater than what had been available so far. This was quickly taken advantage of, at first in countries of the North Atlantic world, leading to what has come to be known as the industrial revolution. A *significant* contribution of these changes (I consider it as the most significant) was in the development of new means of transportation, in capacity much larger than what had been available before. Populations had been limited in size and geographic location by the need for all to live near places where food was produced. Those limitations disappeared with transportation bringing food from far away, bringing people to regions that had so far been inhabitable, resulting in an increase in the world's population. We are in numbers today close to ten times as many as we were in James Watt's day in a society largely converted by necessity from rural to mostly urban living.

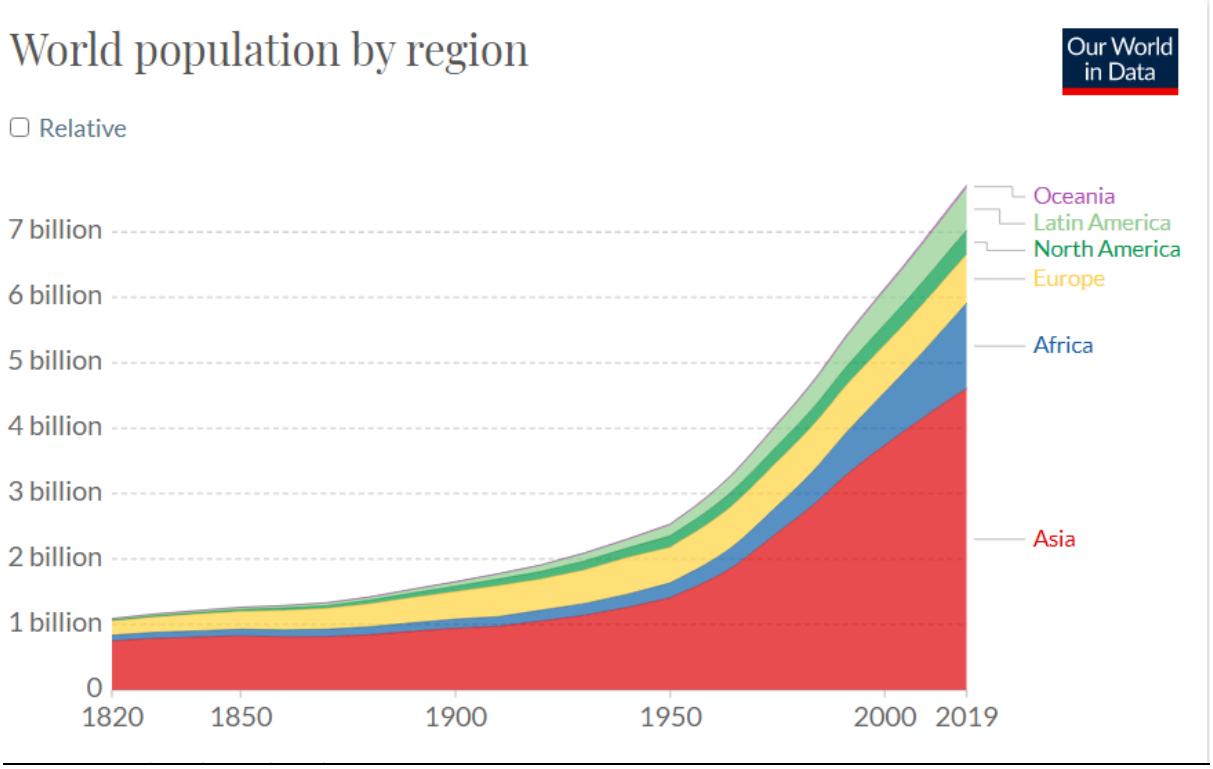

Fig 1

industrialization

Population growth and urbanization demanded new products, leading to the development of industry. Iron and steel as a significant part thereof started increasing in the early 1800's, a few decades after James Watt's steam engine and had, before the end of the century, led to such things as railways, locomotives, a network of transportation that included parts of what was then undeveloped world. This did not come without generating major changes, societal as well as material. Societal changes coming with more urbanization and country interdependences were not seen as something entirely new, they were managed by the institutions and governments already in place.

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But, it is material, physical changes that led to problems for which society was not prepared, other may be than for having been warned of their coming by a philosophers like Malthus and a few others. It is by the middle of the 20th century, after world war II, that material problems began to become of real concern, initially to members of learned, academic communities, brought to the general public's attention by the media and other publications. Most significant in that respect were studies conducted by an international, mostly academic community known as the *Club de Rome* (to which I participated with the Princeton team) in particular the publication in 1972 of a book by *D.Meadows et al*. at the *MIT*, suggestively entitled *The Limits to Growth*. The gist of what it said was in the form of a warning saying

... that if the increase in human presence, the increase in population and industry were not stemmed, reversed, then in the near future, in a few decades, major problems would affect society and life on Earth[1].

That this generated worldwide attention at the time was illustrated by the fact that the book was translated in 30 languages, ended up with 30 million copies being printed. Journals and magazines (including even *Playboy* !) published articles and commentaries about it. The *New York Times Review of Books* had to devote a special issue to this abundant literature (April 1972).. What the *Club of Rome* and other studies were recommending was in fact that people reduce their standard of living, have fewer children, asking business and industries to reduce their size, their productivity. This was asking people as well as leaders of the establishment to change their views of the future, have '*reduction*' replace the '*growth*' trend that was going on. But '*reduction*' is not part of human nature, not part of business practice, it was not well taken and therefore little took place while...

..talking about the population's growing size as a problem became a taboo, a taboo that exists to this day, a testimony to the fact that we humans cannot collectively do things toward a single common objective that demand the participation of the entire global population. That this emerged now is that it is only in the decades following world war II that full globalization, material as well as societal became a reality, a major event in the development of humanity on Earth.

It is not that the problem was ignored by all. The *United Nations* had initiated a series of conferences called *World Summits on Sustainable Development*, one every 10 years beginning with *Stockholm 1992,* to be followed by *Johannesburg 2002* . A significant expression of reality came when *W.Lutz* and *M.Shah,* two research scientists with *IIASA* (a reputed international research center-think tank located in Laxenburg, Austria) wrote a letter to the journal *Nature* before the conference .

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Leadership at Johannesburg

Political difficulties may stifle the impact of next week's sustainable-development summit in South Africa, but researchers and others must continue to pursue solutions to sustainability issues despite a lack of direction from governments.

Fig. 2

D. Meadows et al. *The Limits to Growth* Potomac – Universe Book (1972),

We read in its first paragraph :

."Population as a key compound of sustainable development should figure prominently on the Johannesburg agenda. Yet, after four preparatory meetings for Johannesburg 2002, the topic is still absent".

The letter was published by *Nature* (22 August 2002), together with the journal devoting its own Editorial repeating the same message. But in the end the subject of population was not included in the agenda. Nor was it included in the agenda of *Rio 2012, the* next conference in the series, in spite of the fact that the world's population had grown from about 5.5 to over 7 billion since the *Rio 1992* conference, the world's global *GDP* from $24 to $71 trillion.

With about 50,000 participants including state delegations and heads of state, the agenda of *Johannesburg 2002* ended up consisting of mostly papers devoted to proposed solutions to mediate problems, like fighting hard living conditions and diseases, doing something about improving regional transportation in developing countries, etc…. Working on these problems is what *"sustainability"* in the title of these conferences had come to mean, with nothing said about curbing the rise in population.

It the first time humanity had become globally conscious of being affected by changes resulting from things happening on different time scales, the *short term* (days, weeks, a few years at most) affected by things having taken place in the *long term* (decade, centuries, ...). It was also found out that members of communities could not be convinced to bring stress to their *short term* behavior by doing things for the benefit of others in the *long term*, others they shall never meet.

consuming energy

Today's overpopulation, industrialization is the result of our having discovered a way to extract mechanical power from thermal energy, most of it coming from fossil fuels. This did open the door to a whole set of new possibilities, one of them mechanized agriculture and transportation , precisely what led to the exponential growth in numbers we see. Also leading, at first for some and later to potentially most on Earth to a spectacular improvement in what is called the *quality of life.* This continues to this day with larger populations leading to larger consumption of energy. The two are fundamentally related to each other, a situation in which energy has and will continue be the leading factor. One of energy's most visible contributions is in the presence of industrial facilities all over the world, an increase of the geopolitical importance of regions where sources of fossil fuels, petroleum in particular are found (the Middle East the best case thereof).

Population and industry's size continued to grow, with growth described by the media and books in a number of ways, most in flattering terms describing novelties in living conditions with no mention of the undesirable consequences, the impact on our physical environment. Impact on the environment is sometimes appropriately be called the *' human footprint'*. It turns out that a most important factor affecting the *long term* changes of life on Earth is measurable by a single factor, the amount of energy consumed. Fig.3 shows

today's global consumption as well as how it has evolved since the beginning of the industrial revolution. It also confirms that somewhere in the 90 percents of it comes from fossil fuels,

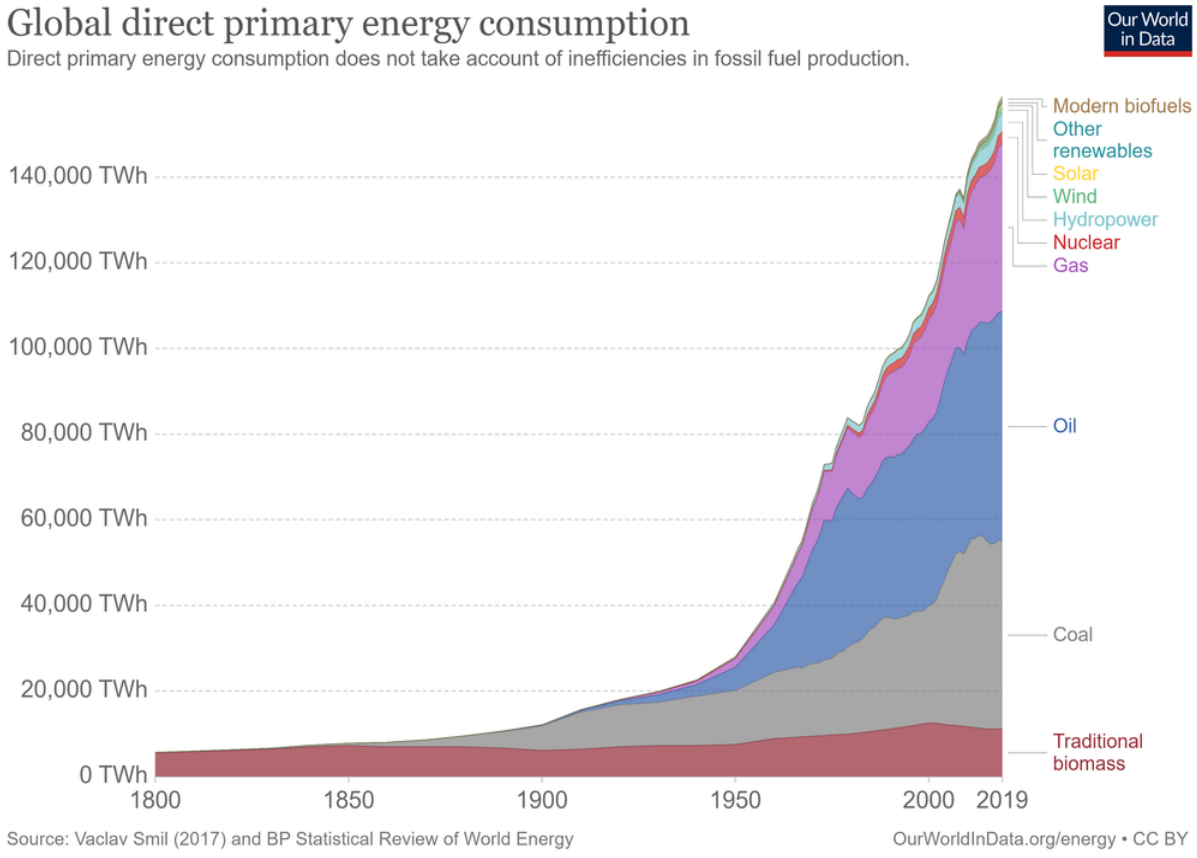

Fig 3

Significant to note is how little change in past centuries reflected by the above (the long term) has been influenced by the events that belong to the short term events having taken place at the time, natural like earthquakes or manmade like politics and wars ..... Two separate worlds.

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global warming

One of the problems predicted in the 1970's by the *Club of Rome* studies was in the rise of pollution. But other than for predicting that it would become most harmful to humanity by the first quarter of the 21st century (where we are today), giving no details as to what that pollution would consist of. It turned out that this is indeed happening, with pollution in the form of gases, residues from the burning of fossil fuels, mostly CO2 accumulating in the upper atmosphere. How this results in global warming is that there are two factors that influence the Earth's temperature. First is heat coming in from the Sun by radiation, then heat radiated back by the Earth to space. It is that cooling resulting from the latter has become impeded by the greenhouse effect created by those residue gases in the upper atmosphere that results in global warming. That industrialization holds an

important responsibility in this process is confirmed by fig.4 that shows that it is the most industrialized regions of the world (North America, China, Europe) that emit most of the CO2.

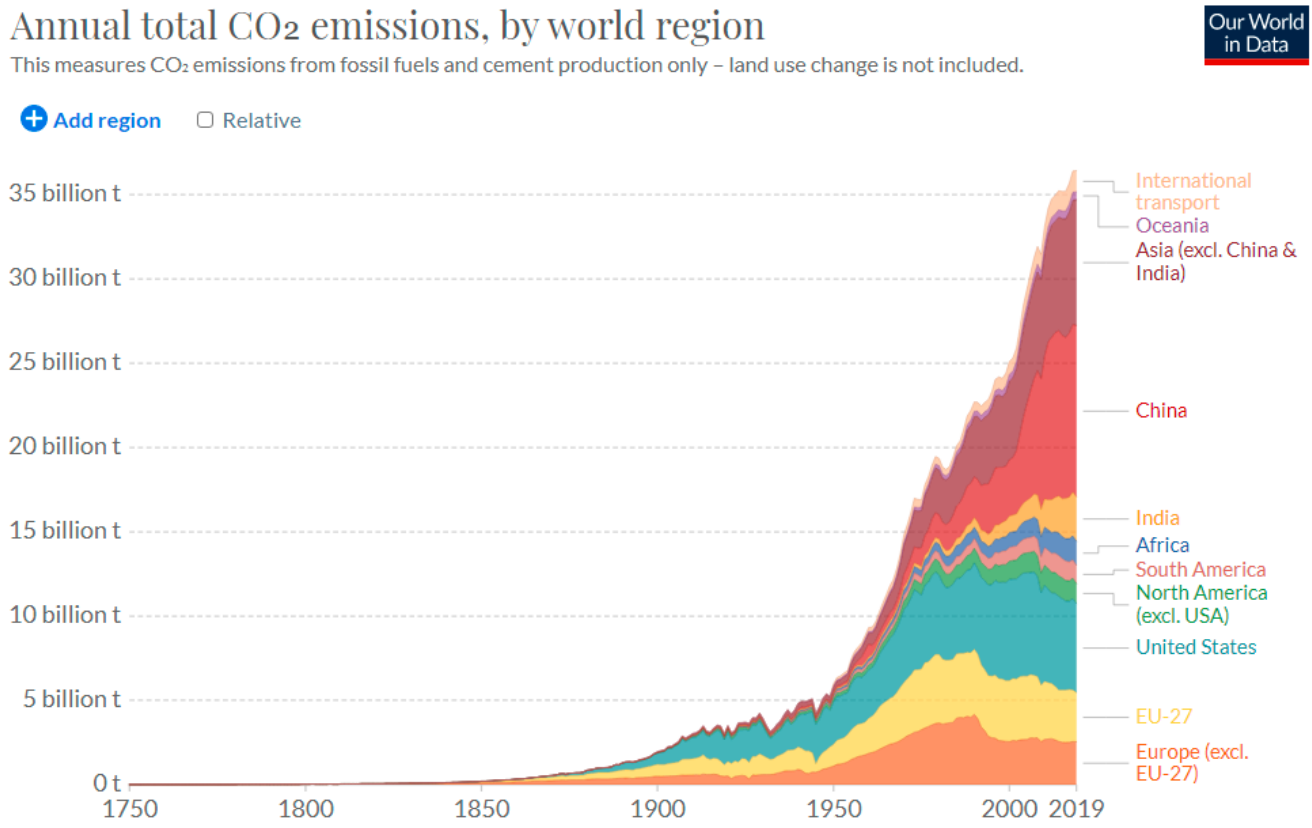

Fig 4

The adverse consequences of global warming have been recognized and addressed for some time. The United Nations began organizing yearly *Climate Change Conferences* referred to as COP, the first in Berlin in 1995. They have grown exponentially in size from small working sessions into being amongst the largest worldwide conferences. Among them was COP3 held in Kyoto Japan that gave life to the Kyoto Protocol in 1997, the first agreement to bind industrialized countries to reduce emissions within given limits.

The importance given to COP21, also known as the *Paris 2015 Climate Change Conference* resulted from the fact that this time delegates were no longer those who impose limits and reductions to countries, but governments were asked to present their CO2 reduction proposals, having the potential of bringing important economic consequences . The resulting so called *Paris Agreement* came in the form of action types, by order of importance

emission reductions, carbon price, bonds insurance,

renewable eergy, energy efficiency, resource consumption

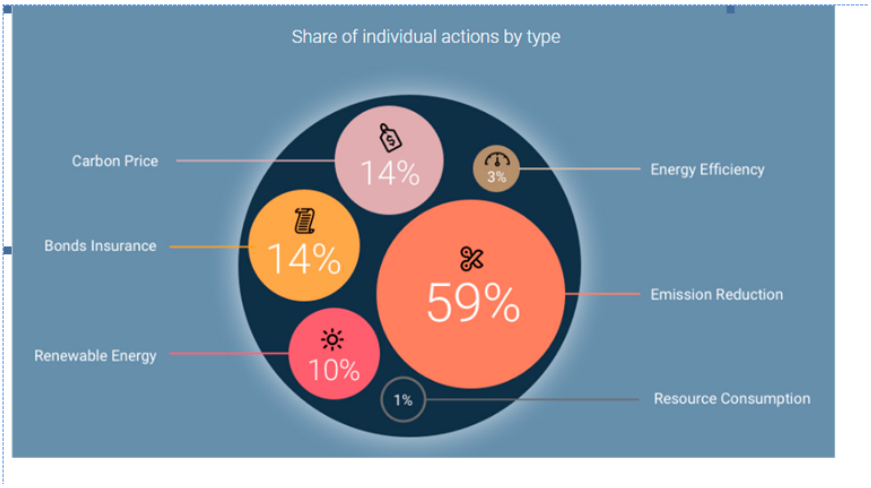

Fig 5 Action types of the Paris-2015 Agreement.

In spite of its predominant importance , reducing human population on Earth is ignored.

The stated objectives of the *2015 Paris Agreement* were indeed addressed - mostly by asking for a reduction in the emission of greenhouse gases, in particular CO2.

But what figs. 1, 3 and 4 tell us, quantitatively,L is that there are realistically two ways in which this reduction could be achieved,

- *by increasing the amount of non-carbon, renewable sources of energy.*

- *more so by reducing the size of our population. leading to lesser amounts of energy consumed. The relationship of CO2 emission with population size is indeed confirmed by noting the similarities between fig.1 (population) and fig.4 (CO2).*

Yet, population was not included as an '*action type'* in the *Paris 2015 Agreement* (fig.5), a repeat of the Johannesburg 2002 story. In the end, the main thing that the 2015 *Paris Agreement* did ask is for a reduction in our use of fossil fuels.

But the absence of asking for a parallel reduction in the world's population shall mean little reduction in the demand for energy consumed..... leaving unanswered questions. which as what follows explains, is not the end of the story.

the further away future

Of no real concern today , but will in a few generations is a most significant problem that is coming : the amount of remaining fossil fuels is finite, it shall not last more than one or two centuries. Fig.6 shows an estimate of how this is to take place. It may well be that it is only an estimate, that it does not include the finding of new oil rich locations, does not include fracking and the like that may change the numbers, but as was said decades ago in the same context by Charles Galton Darwin [2] : *'for the present purpose it does not matter if these are under-estimates; they could be doubled or trebled and still not affect the argument'.*

[2] in *The Million Years,* (1953, Doubleday, New York) Charles Galton Darwin , a grandson of Charles Darwin.

Close to ninety percent of the energy we consume today comes from fossil fuels, losing the latter with no other changes (population !) leaves a gap asking that renewables take over, that the amount of their contribution be sufficiently increased. Which is easy to say, but that it can be done *in sufficient amounts* is so far a question far from being resolved.

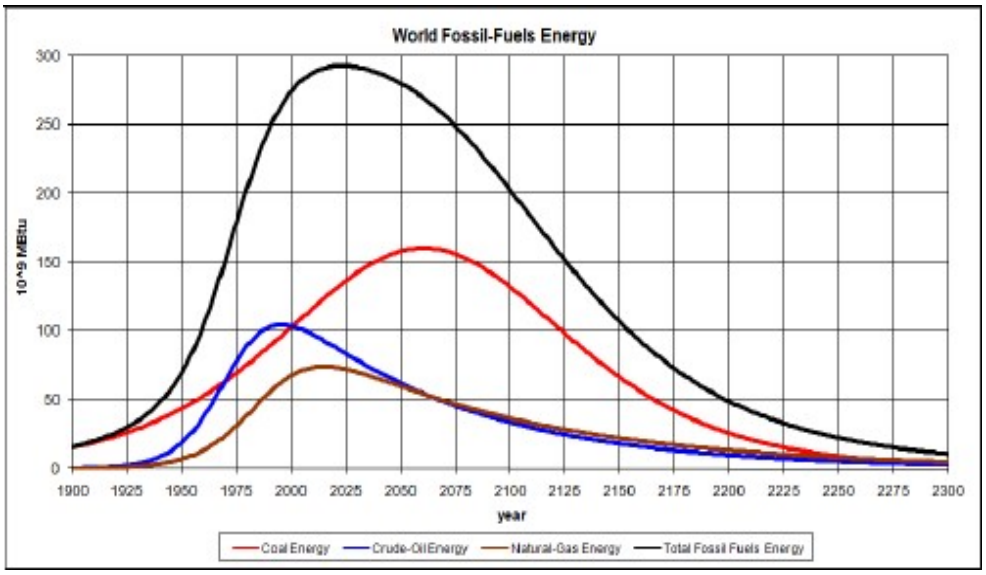

fig 6

renewables

The search for renewables (meaning energy that does not come from fossil fuels) came perhaps first with the intent to combat global warming. But after the exhaustion of fossil fuels we shall be limited to renewable energy, that should be in amounts *comparable* to today's world consumption. What has been achieved so far in the pursuit of renewable energy may be seen as the top right corner of fig.3. It is not very impressive. . Reality depicted by that figure is that replacing the energy from fossil fuels by half or so (a credible guess as to what would be needed to have a sensible effect on global warming) and not reducing our population size (whence not reducing its consumption of energy, experience has shown that we humans are not willing to change our lifestyle) would require that energy from renewables be increased somewhere to between five or ten times what it is today, and that this be accomplished in the next few decades.

The question is of course as to whether that is feasible. What fig.3 shows is how little the year to year increase in the production of renewables, what the total over the past few decades has been. What we see are numbers that include the contribution of thousands of factors that come from

-- science (what is theoretically feasible) ,
-- development (what facilities, what scientific , technical and other appropriately trained personnel, manpower exist),
-- politics and economic (which countries have agreed to stop- start doing what, given their own problems and interests ?).

But the three communities involved (*scientists, engineers, economists*) hardly work together, they do not speak the same language, they read their own professional journals, their own literature. The resulting lack of collaboration while pursuing a common objective is undeniably a reason for the less than impressive achievements having taken place in the matter, with little hope of things getting better, the science/academic component of our civilization is only becoming more divided in separate disciplines, sub-disciplines, the opposite of what is needed.

One renewable much talked about (the only that is not coming directly or indirectly from the Sun) is that of nuclear power. By contrast with much of popular belief, fig.3 says that today's contribution of nuclear power to the world's energy consumption is no more than a few percent of the total (more so, as some do, by considering the generation of electricity alone, but that is not the global picture and does not count). And looking at how little this number has increased over the past few decades leaves one with little expectation that it will change by much. In fact, influenced by *the greens*, France decided recently to reduce its production of electricity from nuclear power, something they were the leaders of, they decided to gradually eliminate their nuclear power plants. And so did Germany

There is plenty of nuclear energy at the atomic level . The problem is in getting it in forms useable at the human scale. What we use is so far obtained by nuclear fission. We hear of nuclear fusion, of the huge amounts of usable energy it might generate. But feasibility is not at all established, the sentence "*feasibility shall be established in 30 years or so*" has been repeated without change for long (more and more so with a smile). Latest is the large *ITER* international project going on in Cadarache, France. Even if feasibility were established, the enormously sophisticated equipment and technically educated personnel needed (which is what nuclear fusion power generation stations would ask for, in addition to being large) and the logistics and politics of distributing energy from big generation points to far away regions are fraught with problems, some realistically intractable.

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epilogue

In the absence of a community of *'scientists, engineers, economists'* that talk to each other and agree together as to where we stand and what can be done, almost anything goes. (being there at the right time, an important part of my own career has been in bringing them together before things they needed to do with computers could be done. I learned as much as they did). In the absence of a community not affected by the *'no talking about the population taboo'* and in spite of the multitude of media (and other) reports of people dying because of overpopulation resulting in poverty, malnutrition (though too often attributed otherwise) we see *UN* agencies such as *UNESCO* funding, lauding efforts to save people's lives We drown in the number of publications , books, saying things that go nowhere, some very specific that contradict each other. And the standard way for country governments, for corporations to show their well being is by quoting the increase in their *GNP* or its equivalent, in so doing aiming at increasing the human footprint, the opposite of what is needed. Not very good !

There shall have been in the millennia long history of life on Earth a period of a few centuries - that we may call the *fossil energy bubble* and that we are in the middle of - a period that began with *James Watt et al* finding ways to use energy contained in *fossil fuels* to generate mechanical power. What we live today is a *golden era* (golden for us) , enjoying the benefits of a civilization made possible by consuming large amounts of that energy , that we get by not much more than having to dig holes in the ground. But that will end, what we shall leave is a world where energy shall be much harder to come by (no more fossils), an overpopulated world already environmentally damaged by our excessive exploitation of natural resources, a world where we have already managed to eliminate many of the (other) species that were still thriving at the onset of the industrial revolution.

It will take a long time for life on Earth to find a new balance, with a population presumably smaller, in a world less hospitable than that we know today.

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Robert Vichnevetsky, born and educated in Brussels, was as of lat professor, now emeritus (Princeton, Rutgers, Computer Science and Aerospace Engineering). He was in industry prior to his academic career, in the 1950's with EAI's European Computer and Research Center, participating in every segment of the recovering European industry, including the development of nuclear power in France and Great Britain. He came to the US in the 1960's as director of EAI's Princeton Computer and Research Center, working among others with NOAA, with NASA's space program, became an Associate Fellow of the American Institute of Aeronautics and Astronautics . He has throughout most of his career also been involved with the development of the international community of scientific societies that emerged after the war, was in that respect part of a working committee with UNESCO- Paris establishing rules for everything rules for things that were new, , including rules of ethics for the community of scientists burgeoning world wide across international political and cultural boundaries, He was for a number of years president of IMACS, the International Association for Mathematics and Computers in Simulation that organizes international conferences and publishes scientific journals (Elsevier and World Scientific). He was in 2005 inducted in the International Hall of Fame in Engineering, Science and Technology