



our changing world – 2
the fossil energy story

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INTRODUCTION

We have created an industrialized civilization based on technology and an abundant use of energy, something that was made possible after it had been discovered that energy in the form of heat could be converted to mechanical power (re : Watt’s proverbial steam engine.. ca 1795). There were large amounts of energy available in the form of solar energy fallen on Earth over the preceding hundreds of millions of years and residing under our feet as coal, oil and gas, convertible to heat, then mechanical power by simply burning those fossil fuels. Before that and other than for windmills and the like, the only sources of mechanical power were muscular, human and animal.

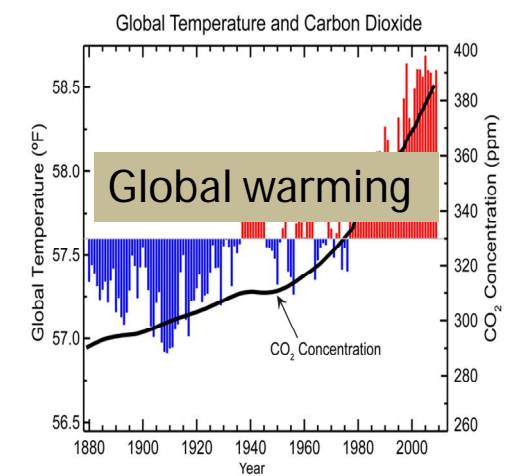
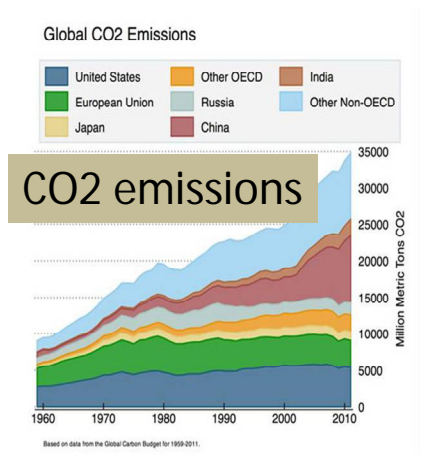
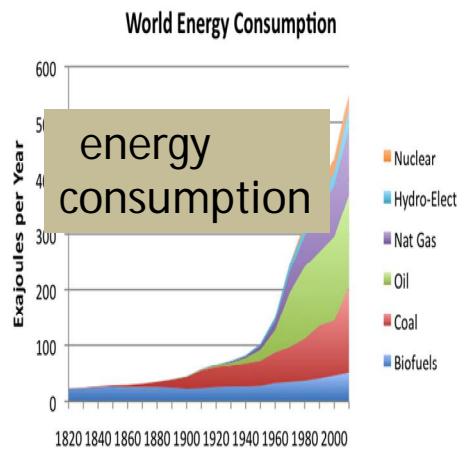
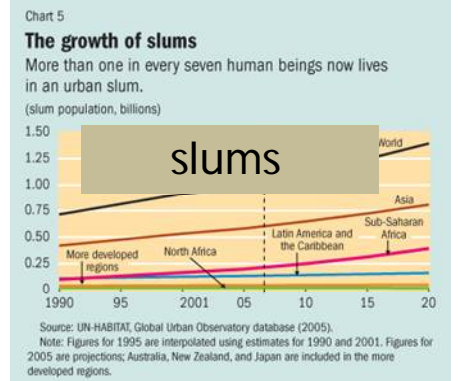
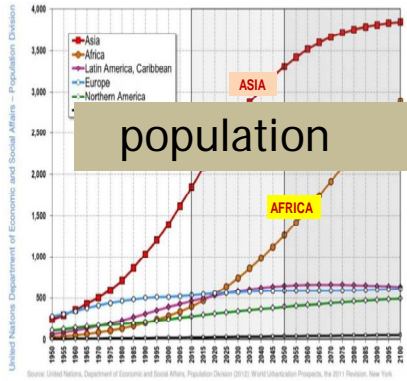
This new source of energy, available in large amounts, generated significant changes to human society, to its size and its ways of living, the latter lauded to this day. But things did eventually turn out not so well, as illustrated by the appearance, in particular by the mid-20th century of a multitude of new problems, some material such as environmental change, global warming and other consequences of environment pollution, some societal such as political turmoil at the global level, destructive wars and forced mass migrations.

Other things have also changed. New means of communication and the power of the media have resulted in the awareness by many of those problems. It is however the case that the mechanics of this changing world are complex, not well understood to this day by the scientific establishment that is equipped to understand separate problems one at a time, not when it comes to accounting for their multiple interactions. Likewise for the general public and most of the governmental bodies, informed mostly by an unprepared media. Adequate reporting on this new situation would required that media staffing be educated in material world’s affairs,

in science and technology, something that it is not because that had not been required in earlier days. In short, today's media is not really able to explain the new world in which we live, which does not prevent said media (and others) from doing so anyway, resulting in that the general public and most governmental entities are, while unaware of it, seriously misinformed. One is inevitably reminded of the parable of "*the blind leading the blind*".

It is however the case that much may be learned by looking at how we have been brought to where we are, looking in particular at what happened in the decades following world war-II which is when much of the visible material and societal changes began to manifest themselves. Consider in that respect the Arab Spring that began in Tunisia in 2011, together with Angela Merkel's 2013 open door policy for migrants to Europe, together with Paris COP21 Conference of 2015 that was in fact the 21st in a series of annual conferences on Climate Change organized by the United Nations beginning with COP1 in Berlin, 1995. That these changes, and many others have all taken place in the same short period of time (a few decades) suggests that there must be a common cause, something more general happening on Earth. Very arguably, that "*common cause*" is human presence, both its population and industry that have grown in size, with a rate of increase that greatly accelerated in the second half of the 20th century. This is also when new technologies and manufacturing capacity that had come with the war had gone through a phase of significant development resulting, in particular, in creating a capacity of transportation on Earth (cargo ships across oceans, pickup trucks in rural areas, etc...) resulting in global mobility for people, food and other material goods, a mobility larger by orders of magnitude than anything that had existed before. Significantly, all of this was made possible by an apparently endless, so it was felt, availability energy. In the past, nature had limited populations in size and geographic distribution by imposing the necessity for all to live near natural food resources. It is, with the newly found mobility, the removal of that limitation that led to the world's population increase, its size being today fifteen times what it was in James Watt's days. And inseparable from population was industry consisting of factories producing goods as well as such things as housing, roads, transportation, etc... the whole consisting of a system of interdependent, inseparable components growing consistently together in size. Some of this is illustrated in figure 1 below, consisting of actual, published data describing the history of a number of important variables over the past few decades, the past few generations.

It is significant to note that what this shows forms a consistent whole that describes the dynamics of what may be called the material world, a real world that shows little influence from the 'official world', that covered by the media, the daily press, that referred to by leaders of governments and industry in their declarations. We live in a world of "two cultures". Its management has traditionally taken place within the official world, but it has been the case over the past few generations that new problems coming from the material world have become of primary concern, This is something we, humanity, have in our development not been prepared to handle.



--- It is after world war II and taking advantage of new technologies the war had generated that human presence and industry, human activity on Earth started growing exponentially. The above actual data, shows a number of resulting developments, some unbearable (global warming one of them). Growth, including that of population, should be halted, reversed. But given the consistency of the multiple factors contributing to this growth it is hard to imagine that this could be accomplished in the short term (a few decades, a few generations) by human intervention.

--- We are at a turning point in human history, a turning point that began a couple of centuries ago when it was found that the energy contained in fossil fuels could be converted into mechanical power, leading to the industrial revolution we live. Our modern civilization depends on massive use of that energy, it could not be without it. But its existing amount is finite, will be exhausted in a matter of one or two centuries. What shall be left is an irreversibly damaged world, depending on so called renewable energy resources, a world where life shall be way less prosperous than that we live today.

--- By contrast with what some may tend to believe, what is happening today is not a "crisis" that will end when today's problems will have been resolved. The facts are that there is no possibility for life on Earth to return to what we think as normal, the way it was one or two centuries ago.

--- Our modern civilization was built on, cannot survive without energy. It is hard to imagine what shall be when fossil energy shall be exhausted, which shall be the case in a few centuries, with no certitude coming from the science engineering community of other sources of energy, the so called 'renewables', to provide energy in the amounts needed for our civilization to survive in the expensive way it does today.

the 1970'S.....THE CLUB OF ROME

Today's world population is three times what it was in the 1950's (with most of the increase in Africa and Asia), the world's *GDP* (related to the global amount of industry , the use of energy) more than ten times. Other than problems coming from what is referred to as pollution (global warming one of them), we have reached the point where the excessive demand for natural resources is giving rise to other problems. The coming of this was predicted in the 1970's as part of privately initiated, non-governmental research conducted jointly in universities in the US, Europe, Japan, research known under the name of "*Club of Rome*" (to which I had the pleasure to participate). A good summary of its nature and results may be found in a 1972 book entitled "*Limits to Growth*" by D. Meadows *et al.* from the MIT, a book that was translated in 34 languages and of which 30 million copies were printed. Its summary was a warning to the effect that the world's growth in population and industry should be stopped, reversed because not just the demand for food as had been Malthus's main argument , but also such things as the rise in pollution (re : today's global warming) would become unbearable in the early 21st century. Books and articles were published by others at about the same time, all saying more or less the same thing. This was big news. Communicated to the public in the form of journal articles and books was the existence of those studies and of what they were saying. So important was this literature that the *New York Times Review of Books* had to devote a special issue commenting on this published work (February, 1972).

But with few exceptions such as the one child policy of China formulated in 1979 that hardly slowed the growth rate of the Chinese population, little took place in response to those warnings. After a few decades the media stopped reporting on the matter (something called the "*nothing can be done about it*" syndrome by Tom Fenton's in a 2005 book entitled *Bad News*), interest was lost by the public and the subject, including talking about population and reversing population growth became a taboo, is still to a degree a taboo to this day. It is what is called *the elephant in the room* when not mentioned in discussions where the subject should be mentioned, but is not.

the 2000's A NEW WORLD

It is in the late 1900's, early 2000's that the material world began to change significantly, that the problems predicted by the *Club of Rome* studies did reach sufficiently visibility to regain the attention of the media , that of the general public. By contrast with the *Club of Rome* days when only the existence of studies and a summary of their conclusions made it to the daily news, information about details now came with plenty of visibility, images in home TV's of disturbing things happening on Earth - shown literally worldwide but with little if any real explanation of the reasons for this new situation. As I said before, giving such explanations would have required that the media, the main source of information

for the public at large, be staffed with reporters, journalists educated in world economics, in the physics of the environment, an education that had not been needed in earlier days and that they therefore did not have. It is not that those unprepared journalists are not trying to explain things anyway, often giving a questionable account of reality. Saying that the fundamental cause of the new problems was in the presence of too much population too much industry on Earth (the *Club of Rome* message) was, still is a taboo.

This leaves the general public little and incorrectly educated about the causes of the many negative changes observed lately in the world, which is also the case for those in governments in most countries (their main source of information is not much better). Negative happenings due to change are inappropriately attributed to a variety of causes, most not related to the real problem, which is that there is too much global growth. The start of the Arab Spring (2011) was attributed to economic mismanagement of Tunisia without mentioning that the Tunisian population had tripled since the 1950's. Much of the flux of migrants across the Mediterranean is attributed to wars in Syria with no mention of the fact that the population of Syria and surrounding Middle Eastern/North African countries had increased by a factor of about 4 over the same period of time, increased population that, other than going with an increase in the dependence on energy, is leading to more greenhouse gases and also inevitably leading to unemployment, poverty, conflicts and wars. This was ignored by the much quoted Paris COP 21 whose official agreements on Climate Change (2015) were :

“ *reducing greenhouse gases emissions by 2025-2030*”

“ *adapting or reducing vulnerability to the effects of climate change*”

with no mention of population, nor of the fact that it is predicted to reach 8.5 billion by 2030, an increase of 20 percent over 2015 presumably followed by a similar growth of greenhouse gas emissions.

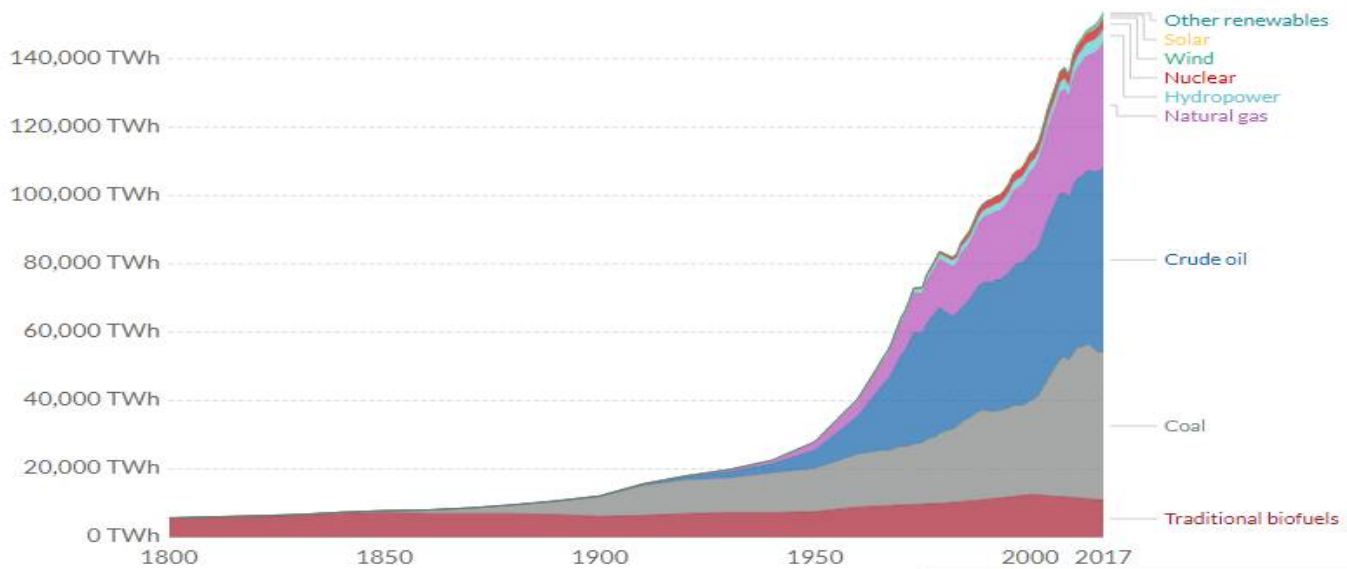
Fossil fuels are today the only source of energy available in sufficient quantity to satisfy today's demand. But its use leads to the release of carbon loaded gases in the atmosphere, resulting in greenhouse effects that are a main source of global warming, climate change. Measures taken to attempt fighting global warming include the development of so called renewable non-fossil fuels, non-carbon loaded sources of energy (solar, nuclear, hydro, ...).

It is not that the development of those resources is not taken seriously, developing renewable energy resources has been under way for decades, but the results to date have been minimal. By contrast with fossil fuels that come easily by just *digging holes the ground* in many places on Earth, the forms of renewable energy under development do, other than capital, require a significantly large engineering, technical personnel, not easy to come by. For one reason or other, what all the developments of renewables have led to to date is only a few percent of the world's energy consumption (fig 2), unanswered questions come as to why so little and as to whether sufficient amounts of energy shall be available after fossil

fuels will be exhausted.

Global primary energy consumption

Global primary energy consumption, measured in terawatt-hours (TWh) per year. Here 'other renewables' are renewable technologies not including solar, wind, hydropower and traditional biofuels.



In spite of its importance, the generation of renewable energies amounts to date to only a few percent of the world's consumption (top right of this chart), with little sign of new developments possibly leading to more significant rates of generation of energy in the future. There are reasons to ask if renewable shall be available to generate energy in amounts comparable to what our civilization consumes today.

This is quite a different story from what the public is led to believe. The possibility of producing renewable energy in sufficient quantity to reduce CO2 emission in the atmosphere as a way of combatting global warming is not a certitude. Unsaid is that the rate of greenhouse gas emissions shall still be affected by the ongoing growth in size of the population-industry system (fig 1), a growth leading to more greenhouse gas emissions that renewables may have a hard time catching up with.

SOLVING TODAY'S PROBLEMS ?

It must be noted that we, humanity on Earth, do not have any entity, government, NGO or other institution capable not only to understand and predict the new problems we face but also given the authority and power to prevent undesirable developments from taking place. It may be appropriate, to explain this state of affairs, to quote from E.O. Wilson :

... the problem with humanity is that we have created a civilization with stone age emotions, medieval institutions and godlike, space age technology (E.O. Wilson).

The *Club of Rome* did, half a century ago predict the coming of problems, predictions that came to be generally verified. But the *Club* did not have the authority or power to do anything about it.... So, in the absence of a credible common understanding of the situation, what we see is a multiple attempts to save the world from its globalization problems, attempts that are often misdirected, their ensemble chaotic, to say the least. Ignoring that overpopulation-industrialization is today's essential world problem (for example in its contribution to global warming), we see that governments (and multinational corporations that surreptitiously - but *de facto* run much of the world) do not mention in their day to day decisions and declarations what goes on with the material aspects of the world, those illustrated in fig 1. Mostly local self interest and politics, illustrated by the fact that they keep using "growth in GNP" as a measure of success. For instance, at the closing of the 2018 G7 meeting in Quebec where some of the concern had been about climate change, we heard *Christine Lagarde*, at the time managing director of the International Monetary Fund say something like "the world's economy is not doing so bad, in spite of difficulties, we may nevertheless expect an increase of 2 or 3 percent of the global GNP next year". Unaware of reality, one finds suggestions that global warming may be caused by people's way of life emitting too much greenhouse effect gases (including methane emitted by cattle : eat less meat !), not that there are too many humans on Earth, consuming too much energy in the first place.

Then also the media, next to describing deadly famine in diverse locations of our overpopulated planet, lauds reports on advances in medicine that will save millions of lives, which sounds great but is doing the opposite of what solving our fundamental, long term problem of overpopulation demands. Likewise for the *billionaire foundations* that do not help by bringing supplies to starving populations, of which there are many in the world.

Humans, beginning as hunter gatherers of the stone age, had little or no knowledge of things happening elsewhere, and had no concern with the long term. Their world was *hic et nunc* "here and now". Our emotions and institutions are still to a large extent those we have inherited from those earlier times, emotions and institutions that do not serve us well to manage today's global problems or preventing future degradations to happen

Paraphrasing E.O. Wilson :

..... *a problem with modern humanity is that it relies on politics and societal principles to address material problems that belong to the sciences, demanding knowledge and rational thinking about facts and hard numbers, not opinions, beliefs and theories.*

So, instead of an institution or institutions understanding today's world problems and having the authority and power to impose guidance toward a solution, what we see are separate actions intended to eliminate what are no more than separate symptoms of a global problem, intended to solve local problems with little thinking (and most probably understanding) about the rest of the world. Which results in a variety of proposed and ongoing projects intended to

improve one aspect or other of the global situation, their originators declaring on their own and without coordination with others the merits of their contributions, declarations that the general public believes in the absence of other guidance.

the long term ... THE FOSSIL ENERGY BUBBLE

In a few centuries from now, historians of the world will talk of the pre-fossil fuels era that ended in the 18th century, of the post-fossil fuels era they shall be living in at the time, and of a relatively short in-between period that we may call *the fossil energy bubble*, that we live in today. What started with James Watt's steam engine a little over two centuries ago led to our reckless use of the energy contained in fossil fuels. But humanity is approaching the time when these will be exhausted, other sources of energy shall be needed with as yet unanswered questions as to whether we shall not only have sources of replacement energy, the so called *renewables*., but (a too often neglected consideration) have those renewables generate amounts of energy sufficient to satisfy a demand at a scale comparable to what we use today, those illustrated in fig 1 .

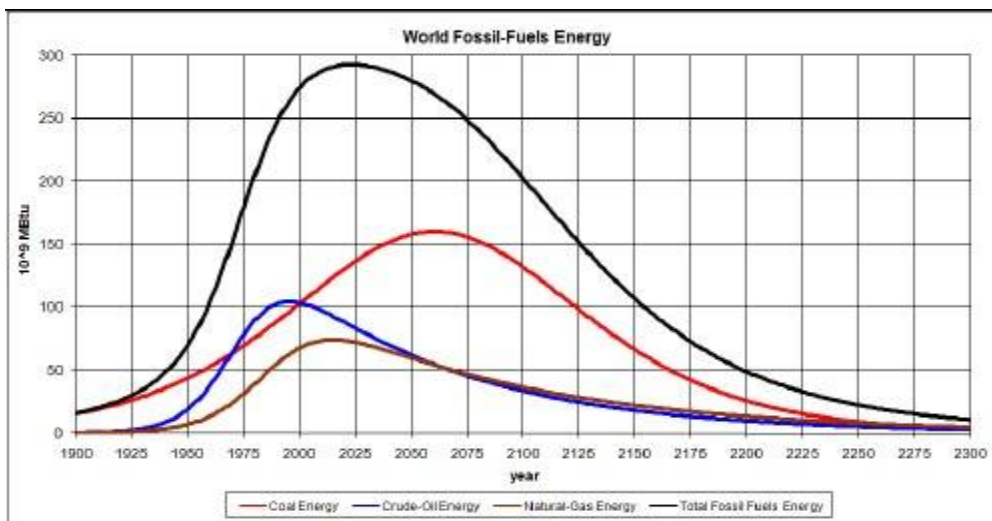


fig 3

Non fossil, renewable energy sources have gained attention for decades because of their low contribution to atmospheric CO2 . Other than for their contribution to fighting global warming, they will, after the exhaustion of fossil fuels, become the main source of energy, that needed to allow civilization on Earth to continue as it does today.

From what we know, renewables shall consist of solar energy, hydropower and windmills, then biofuels and nuclear power. It may well be that Virgin Airlines has flown a few planes fueled with biofuel, and there are other examples of renewables replacing fossil fuels. But that

is only part of the story, numbers must be taken into account. It turns out in that respect that, in spite of the high interest in the matter, the generation of renewable energy amounts to date to only a few percent of the world's consumption (see fig 2), with little sign, so far, of new developments possibly leading to more significant rates in the future. That the amount of renewable energy we will be able to generate will match the demand is, based on today's experience, not at all a certitude.

What we live today I have called the "*fossil energy bubble*". We may be reminded that it started with the discovery in the 18th century that mechanical power could be derived from heat, with large amounts of heat available by simply burning fossil fuels - this leading to the industry and powerful means of transportation that have led our population to significantly grow in size (today 15 times what it was in James Watt's days !). But we begin to feel the decline of this era that comes with the combination of an increasing demand (see fig 1) and the exhaust of fossil energy (fig 3).

As for the future, we have seen that there are expectations, but no certitude to date that sufficient amounts of energy coming from renewable shall be available. But there are two sides to the problem, feasibility of renewables on the one hand, in sufficient amounts to satisfy the world's future needs of energy on the other. These are of concern to very different schools in the world, schools that do not really talk much to each other, nor do they raise a flag about renewable eventually not being able to supply the world with the amounts of energy they will need (see fig 2.).

Finally, the belief that "*scientists will find a solution, they always have in the past*" (an opinion often expressed) is defeated by the not commonly understood fact that the total amount of energy is a given, that it may be transformed from one form to another but cannot be created. It will have taken the time of what I have called the fossil energy bubble, in all around 4 centuries may be a good guess, for humanity to (recklessly !) exhaust hundreds of millions of years of solar energy that had accumulated as an underground energy resource on Earth. So, what we may call the *fossil energy bubble* we live shall have us end with a world that will have to be managed without the easy to come by energy from fossil fuels we have today, a world where forests and many living species will have disappeared

(we are reminded by the media of the ongoing deforestation and of the large number of species that are already extinct) in a materially damaged environment, much of which is already with us. That the energy from renewables will come in amounts sufficient to support the kind of life humanity leads today remains questionable, whence the possibility of a period of forced, hard, painful shrinking of the human population on Earth.

In all, the post fossil energy world shall be way less hospitable than it was in the past. The coming of *power from fossil energy* that has been lauded as a welcome contribution to human's well being will end up bringing irresolvable problems, overpopulation and an irreversible degradation of the quality of life of Earth... Though, borrowing the wording of another proverb, it was all "*paved with good intentions*" !.....

Robert Vichnevetsky, is professor in Mechanical and Aerospace Engineering and Computer Science (Princeton and Rutgers, now emeritus). He was in industry prior to his academic career, in the 1950's with EAI's European Computer Center in Brussels, Belgium participating in the introduction of scientific computing to every segment of the recovering European industry including the development of nuclear power in France and Great Britain. He came to Princeton in the 1960's as director EAI's Research Center, engaged in scientific computing and industrial research and development, including with NASA's space program and the Club of Rome's Princeton participation. He has throughout most of his career been part of the international network of professional scientific societies that had emerged after the war, has been in that context chair of a working committee with UNESCO, Paris and president of IMACS, the International Association for Mathematics and Computers in Simulation that organizes international conferences and publishes scientific journals (Elsevier, World Scientific). He was, in 2005, elected to the International Hall of Fame in Engineering, Science and Technology. rvichnevetsky@aol.com

