Global warming or nuclear waste – which do we want?

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As the conference in The Hague was taking place, the outlook on global warming was increasingly alarming. In spite of the price increase of oil, a good thing from this point of view, and of gas in the near future, there does not seem to be any sign of a reaction similar to that of 1973. Though energy conservation, and the development of renewable energy sources are desirable, it is more obvious every day that these will not be sufficient to stabilise, and even less, to reduce the emission of greenhouse gases. Clearly, it is only through the renewed development of nuclear energy in the industrialised countries that we can obtain a significant and rapid reduction of gas emissions. We need only note that countries like France and Sweden, which produce their electricity without burning fossil fuels, generate half as much carbon dioxide per unit of energy consumed as Denmark whose electricity is produced essentially in coal or lignite plants. It seems paradoxical, then, that the energy supply scenarios put forward by such instances as the World Energy Council do not seem to consider seriously a renewal of nuclear energy. On the contrary, certain countries, like Germany, are considering pulling out of nuclear energy altogether. It's as though the dangers associated with nuclear energy were perceived as worse than those related to global warming. Does this view rest on objective data, or is it not, rather, irrational? We cannot do without thinking this matter through: the future of our planet may depend on the choices we make. We will attempt, here, to initiate such a reflection, as unbiased as possible. The first thing to do, then, is to compare the risks due to nuclear energy and to the production of greenhouse gases from the combustion of fossil fuels.

Nuclear risks

The risks associated with nuclear energy are well identified: major accident, diffuse irradiation, the handling of nuclear waste, proliferation. Though the dangers are real, they are, in general, over played by systematic opponents to anything nuclear, inducing reactions of fear that are out of proportion with the true danger in large fractions of the population, that professional anti-nuclear militants know how to make the most of. A detailed study of these risks is, of course, out of the scope of this paper but some considerations seem useful here to place the risks in perspective. First, let us remind ourselves that we are all exposed to natural radioactivity whose intensity varies by a factor of more than 5 from one place to another on this planet. No ill effects from natural radioactivity have ever been demonstrated. It is thanks to the existence of natural radioactivity (which has the same characteristics as artificial radioactivity) that nuclear industry was one of the first to be able to put in practice the precautionary principle : by limiting the additional irradiation due to human activities to a fraction of natural radioactivity, we can be sure that the effects on public health will be negligible. Claiming that any radiation dose, however small, is dangerous for our health is more political than scientific.

Major accident

Three major accidents serve as reference today: Three Mile Island (TMI), Tokaimura and, above all, Chernobyl. In the first instance, there were no fatal casualties. Two operators were significantly irradiated. There was no irradiation to the public. In spite of this, the TMI accident created a real panic in the USA, leading to, among other consequences, a loss of confidence in nuclear experts. The fact that there were no casualties had, in this regard, no influence. In a way, one can say that, after TMI, the approach to nuclear matters became totally irrational (paradoxically, it seems that only civilian nuclear applications are frightening). Tokaimura was a criticality accident in a fuel fabrication unit. Several technicians were irradiated and two of them died. There was no irradiation of the public. It seems that the communication by the Japanese authorities was catastrophic and the media, worldwide, concurred in publishing scary reports of the event, to the point that some referred to the fact that the criticality accident could have evolved into an atomic explosion similar to Hiroshima. This was, of course, totally impossible since, in the present case, the critical reaction stops automatically when the water boils up. Nevertheless, the Tokaimura accident, which appeared to be similar to many work accidents, had a devastating influence on the Japanese public's acceptance of nuclear power.

The Chernobyl disaster, of course, was on a completely different scale. Fourteen years after the disaster, the acknowledged toll on health, as given by the United Nation Scientific Committee on the Effects of Atomic Radiations (UNSCEAR), accounted for 35 deaths amongst the "liquidators" which occurred at the time of the accident or shortly after, and 1500 cases of thyroid cancer, mostly amongst children. Three of these cancers were fatal. Other kinds of cancer are hard to relate specifically to Chernobyl, because they can appear only as a small increase of 0 to 3% over and above the cancers that would have occurred in the population, even if there had been no disaster Approximately 5 million persons in Ukraine and Byelorussia live in an ambient radioactivity several times higher than that due to natural radioactivity before the disaster. This additional radioactivity is due to Cesium 137 whose half life is thirty years. In such a population, the number of fatal cancers expected to break out each year, in the absence of additional irradiation due to the accident is estimated at 20 000 while the excess due to Chernobyl would be, at the most, using a linear dose to effect law, approximately 500 per year. At the time of this writing, no statistically significant excess has been observed. It has been claimed, recently, and it was confirmed by the Russian minister of disasters, that 15 000 deaths have occurred amongst the "liquidators". It so happens that the mortality tables used by actuaries show that 15 000 deaths should be observed in 15 years in a population of 250 000 persons aged from 20 to 30 years, the age group of the "liquidators". As the total number of "liquidators" was 600 000, we see that the announcement of 15 000 deaths amongst them is not very meaningful, in the absence of more precise data on the population considered, and on the causes of the deaths. In any case, the consequences of the Chernobyl disaster on

Ukrainians and Byelorussians will be far less severe than those due to addiction to smoking and alcoholism. The Chernobyl disaster is considered as the archetype of the worst conceivable civilian nuclear disaster. Nuclear security experts estimate that the probability that a disaster of this amplitude occur with the reactors of the type used in the West is of the order of one millionth per reactor per year of operation. For France, one of the most heavily "nuclearised" countries, for instance, this means that such an event could occur once in 20 000 years. Other types of accidents capable of causing more casualties (dam rupture, explosion of a gas tanker, fire or chemical explosion, fall of a meteorite, tropical storm, fall of a large carrier plane, etc.) can occur with a much higher probability. Like a nuclear disaster, such accidents would have local and/or regional consequences but, in no way, (except the fall of a very large meteorite) global. In no way would the biosphere be threatened, nor any particular species.

Nuclear waste

It is customary to make the issue of nuclear waste the central reason to ban any civilian applications of nuclear energy. People stress the long half-life of these wastes, forgetting to mention that, unlike chemical waste, the dangerousness of nuclear waste is inversely proportional to the life time: the longer the half-life of a nucleus, the fewer the disintegration events per unit time. To what extent is the radioactivity generated by theses wastes a source of danger for the biosphere? In the short-term, the radioactivity of nuclear waste is well confined and under control, to the point where the incidence on health of these wastes is tiny if not nil. The security of deep storage would, as is obvious, be much better than that of surface or sub-surface storage. There is general agreement that, with deep storage, the radioactivity would remain confined for at least one thousand years. If we consider the storage sites as lying at depths of 500 to one thousand meters, we can compare the radioactivity that would potentially be released after one thousand years to that of the first thousand meters of the earth's crust. Working it out (without waste processing or incineration which would reduce the dangerousness by a factor of 100), again in the case of France, we find that the residual radioactivity corresponding to 100 years of production by 100 plants (at this time, there are 57 active nuclear plants in France) would be less than one per cent of the crust's natural radioactivity (due to their large size it would be five times less for the US, for the same level of "nuclearisation"). Thus, we see that deep storage does not represent a danger (barring an accident during transport) in the short or the mid term for people living in the vicinity of the sites and that, in the long term, it does not represent a risk for the biosphere taken globally. There could be a risk locally, in the case of an accidental intrusion within a given site, by drilling, for example. We should note that, because of the long half-life of the wastes still active after a thousand years, the products will disperse in the biosphere before they disintegrate in case they are released from their confinement, limiting, in principle, the local risk. In summary, we reach the same conclusions that we had come to concerning the characteristics of nuclear accidents (in a less severe way): their incidence is local, at the most regional and in no way global. The difference lies in the time scale and, here again, a bit of common sense would tend to convince us that, all things equal, a risk that may arise one to ten thousand years from now is preferable to a risk which threatens today or in the coming century.

Proliferation

The base materials used to manufacture nuclear explosives are Uranium 235 and Plutonium 249. Uranium 235 is present in natural Uranium in a proportion of 0.7% while the concentration of this isotope that is needed to make a bomb is 90%. It follows that isotopic enrichment procedures are required. Up until the seventies, the two procedures that were available, electromagnetic separation, and gaseous diffusion, were cumbersome, expensive, and heavy electricity consumers. Today, two new techniques are available, that are lighter and less conspicuous: gaseous centrifugation and laser separation. By using these different techniques, any country that has the human competence and a minimum of means is able to produce enough highly enriched Uranium 235 to manufacture several bombs. That is what Pakistan has done recently and what Iraq was in the process of doing. Iraq did not have a nuclear reactor. Pakistan had a reactor of the type used in Canada but did not use it to produce the fissile material it needed for its first bombs.

The other fissile material, Plutonium 249, is produced in nuclear reactors. All reactors that operate with Uranium, whether natural or slightly enriched, produce Plutonium that can be relatively easily extracted using chemical procedures. The truth is that none of the military nuclear powers acquired the status of nuclear power by using nuclear reactors built with a view to generating electricity. The transfer from civilian nuclear to military nuclear activity has not, to our knowledge, ever occurred. On the contrary, the inverse transfer, from the military to the civilian sphere has been frequent and explains some of the characteristics of the civilian nuclear industry that might not have been true in other circumstances: for example using enriched Uranium in water cooled plants. It is true, also, that some military nuclear powers, or powers that intended to become such, handled nuclear power reactors in such a way as to extract high quality Plutonium from them It was the case in France, with its graphite-gas reactors, and in the Soviet Union with its RBMK reactors (Chernobyl type). In reality, the countries wishing to equip themselves with commercial power reactors have to sign a non-proliferation treaty and, thus, renounce any development of nuclear weapons.

We see, then, that as far as States are concerned, the fear of seeing civilian nuclear power plants be diverted towards military ends has been futile until now. The States that have decided to acquire nuclear weapons have been able to do so, provided they had the human competence (physicists, engineers) and the material means. As for terrorist groups liable to practice nuclear blackmail, we should consider that the demise of the Soviet Union has, alas, already given them the means to acquire the needed goods.

Risks with fossil fuels

We won't dwell, here, on the dangers due to the production, the transportation and the use of fossil fuels: accidents in coal mines, fires in pipelines (5 000 death casualties in Nigeria a few years ago), explosions in gas pipes (Siberia, Mexico) and, of course, concerning gas, domestic explosions (100 death casualties per year in France) - these are well known. Likewise, we will not dwell on oil slicks, the environmental impact due to working the far North, the wars triggered by the will to control resources and pipelines (Biafra, Kuwait, Chechnya, Angola, etc.). All these dangers, all these wars related to the use of fossil fuels, however dramatic and deadly (much more so than the Chernobyl disaster!) remain circumscribed to the local or regional level and do not threaten the biosphere itself, barring the extension of regional conflicts to a world conflict. We will set our argument on the emission of greenhouse gases.

The use of fossil fuels induces the emission of greenhouse gases: carbon dioxide generated by combustion, in varying amounts (half as much with gas as with coal, for comparable technologies) and methane in the case of natural gas, not owing to combustion, but to leaks. The magnitude of these leaks is estimated at 5 to 30 % for fuel from Siberia, the one that Germany will use extensively to replace its nuclear reactors. Now, methane is fifty times more efficient than carbon dioxide for greenhouse effect, so that using Siberian gas is worse than burning coal, for greenhouse gas emissions, as long as the state of disrepair of gas pipelines persists, and the production techniques in Russia are not improved.

The emission of greenhouse gases induces a temperature increase. The models used in climate previsions are still not accurate enough to give a precise evaluation of the magnitude of the temperature increase which is estimated between 1.5 and 6 degrees Centigrade in the course of the 21^{st} century. The local and regional effects of such an increase are even more difficult to anticipate. Many are the climatologists who consider that, now already, the 0.5 degree Centigrade increase of the average temperature on the globe since 1900 is due to emissions that originate from human activities, and that the temperature increase is accelerating. Many, too, are those who consider, though they cannot certify it, that the increasing violence of cyclones and storms is due to this rapid temperature rise. Others argue that the uncertainties of forecasts are such that it is too early to take determined steps towards reducing the emissions of greenhouse gases. Such an attitude is the antithesis of the application of the precautionary principle which implies, on the contrary, that the worst case evolution be considered, provided it is reasonably likely. In our case, this means a 6°C temperature increase within the century. Even worse, the very long life time of carbon dioxide in the atmosphere will lead to a mean temperature increase on the globe of at least 2°C even if emissions are reduced by a factor of three before 2050. If we were to take no strong action, some scenarios anticipate a temperature increase that could reach 9°C in the 22nd century. While one can hope that a 2°C temperature rise may remain globally acceptable, even if it may lead to local or regional disasters, no one really knows where a temperature rise of over 6°C might lead. Let us recall that, during the last ice age, the mean temperature on the earth was only 4°C lower than it is today. Will the ocean which absorbs half of the carbon dioxide of human origin today continue to play its damping role or, on the contrary, will it turn into an additional source of carbon dioxide? Will the biomass expand, thanks to better climatic conditions, in particular at high latitudes, or, on the contrary, will the eradication of numerous species due to extreme climatic conditions lead to the reduction of the biomass? Is there a risk that the enormous quantities of methane trapped in the permafrost ice of Canada and Siberia will be released seeing that the anticipated temperature increase will be greater than average at higher latitudes? In the event that the ocean and the earth's biosphere should become sources of greenhouse gases on their own, the earth could enter an unstable regime, the temperature rise triggering a sort of snowball effect. The concentration of carbon dioxide would increase while that of oxygen decreases. One can envision the Earth as a stifling and sterile place. Who is in a position, today, to assert that such a scenario is strictly unrealistic? Applying the precautionary principle requires that all possible steps be taken to avoid such a disastrous outcome. The Rio and Kyoto meetings have registered a surge of awareness but the target set by Kyoto, namely to stabilise emissions, a target that is not even close to being met, is totally insufficient to prevent a temperature increase. At best, it will lower the rate of rise. To achieve the stabilisation of the temperature at 2°C above the current temperature, it would be necessary, as mentioned earlier, to reduce the emissions by a factor of three. The timorousness displayed at Kyoto is all the more unfortunate since it would be possible, within ten years, to reduce the emissions by thirty percent without significant economic consequences.

Priorities

From the above considerations, we see that the potential danger due to the emission of greenhouse gases is on a completely different scale from that due to nuclear energy or other methods of energy production. The priority, then, is to pull out of fossil fuel energy altogether. It is only as a second step that we can consider pulling out of nuclear energy, if it can be proved that more secure, less polluting and reasonably competitive techniques of energy production are, indeed, available, and able to produce energy on the scale needed. Ecologists sincerely concerned with the issue should reconsider their priorities and their agenda. They will then agree that the major danger is, indeed, a climatic disaster and that all efforts must be made to avoid such an outcome. Of course, this does not free us from the obligation to remain vigilant towards nuclear applications and also towards other techniques for the production of electricity, such as hydraulic power and biomass burning, the best energy being the energy that is not consumed.

Solutions

France and Sweden, in particular, have demonstrated that it is possible to produce electricity without resorting at all to fossil fuels. They have done so by resorting to nuclear and hydroelectric power. Some claim that, by resorting to renewable energies such as wind or solar energy, similar results could be obtained. It would thus be possible for industrialised countries to commit to no longer build electric plants using fossil fuels, whether coal, gas or oil. The fact that this hypothesis is not even mentioned in the World Energy Council scenarios demonstrates the weight of the lobbies connected to the gas and oil industry and, also, the extent to which the irrational fear of nuclear applications can lead to nonsensical behaviour towards the environment. Let us recall that it took France ten years to build its set of reactors. It should be possible, in the United States, in Germany, in the United Kingdom, to achieve as much, with nuclear reactors, or any other means of energy production, if, as claimed, any alternative is available. To exclude hypocrisy, what are the German Greens waiting for to demand that none of the electricity formerly produced in the nuclear reactors that will be stopped be henceforth produced in coal or gas plants, or imported from third party countries that use such energy sources.

For developing countries, it would be advisable, as a first priority, to convince them to avoid resorting to coal, setting aside, for them, a priority option to use gas, with the provision that gas leaks would be minimised. It is likely, moreover, that large countries like China or India will rapidly resort to non fossil energy sources, including hydraulic and nuclear energy.

The simple fact of resorting to renewable or nuclear energy sources for the production of electricity should allow a reduction by approximately 20% of greenhouse gas emissions. A cut of the same order of magnitude could be secured by banning the use of fossil fuels in, first, collective heating systems, and subsequently in private heating systems. Using the biomass could be encouraged, provided it does not result in deforestation, as is currently the case in many developing countries, nor in diminishing the biodiversity of plants.

The issue of transportation is a more difficult one. It should be possible, in the short term, to allow only clean vehicles for intra urban traffic, whether electric or operated with compressed air, the inevitable consequence being an increase in the demand for electricity. Likewise, long distance transportation should be encouraged to use the railway whenever possible. In the long term, the use of hydrogen, obtained from the dissociation of water, here again requiring electricity, should be considered. The direct association of renewable energy sources that are intermittent in nature to the production of hydrogen could signal the advent of these energies on a large scale and, maybe, the possibility of pulling out from nuclear energy without inducing an ecological disaster.

The confinement of carbon dioxide in gas or oil reservoirs, in salt domes, or by developing forests in desertified zones could be encouraged with grants financed by a tax on the emission of greenhouse gases. The emission permits system could find its usefulness in such applications. In no instance should it be used to circumvent the banning of fossil fuels for the production of electricity or of low temperature heat for housing or industrial heating systems.

Political and economical stakes

As can be expected, pulling out from fossil energy sources will confront interests that are much more powerful than those of nuclear energy. The interests of coal, oil, gas industries, in the first place. These industries are, above all else, particularly the last two, active in the world economy globalisation process. The liberal market rules, which favour investments that are profitable in the short term, favour, today, the production of electricity with gas, the investments required for a gas plant being three times smaller than those for a nuclear reactor, and six times less than those for a wind farm. The problems associated with renewable energies and to nuclear energy are, from this point of view, very similar. Both require heavy investments, both have low operating costs, in particular regarding the fuel, both guarantee energy independence to countries which make this choice, both are contrary to the logic of world globalisation and restore power to the citizens. One would wish that the (legitimate) demand for transparency that is applied to nuclear energy be applied also to fossil energy sources, both on the national level and on the international level. As everybody knows, the oil and gas lobbies are among the most powerful and opaque on this planet.

Banning stereotypes and pretenses

We think that one should pull out from fossil fuel energy sources as quickly as possible. As a first step, there is good ground to demand that no new electricity production plant be allowed, whatever the circumstances, to resort to fossil fuels. One must, also, ban importing electricity that is produced from fossil fuels. If some countries believe that they can make this commitment and still pull out from nuclear energy, they will succeed in demonstrating their sincere commitment to ecology and will be in a position, but only under these conditions, to be taken seriously in their will to preserve the environment. Other countries which doubt that renewable energies would be sufficient should be free to resort to nuclear energy without being pointed to as the bad dog.

Appendix

The risks associated with radioactivity and irradiation in general are, usually, measured in Sieverts. For most people, even scientists, this unit has no real meaning. It may be useful to make a comparison with well known risks that have similar consequences. Those related to tobacco smoking are especially relevant since they are essentially related to cancer producing processes. The following tables compare the risks associated with irradiation with those associated with cigarette smoking. They are based on the following dose-effect relations: 0.04 lethal cancers per Sievert, and 1 lethal cancer per eighty thousand cigarette packs. It is assumed that if the dose-effect relations are not linear they remain proportional between the two hazards. Tables I et II are constructed in such a way that radiation doses and the number of cigarette packs smoked lead to the same number of premature deaths.

[1] *This article is adapted from an article published in Bulletin de la Société Française de Physique N° 126, p.15 (oct.2000)*

TABLE I
Comparison between effects of some irradiation exposures and of cigarette smoking

	Annual dose in millisieverts	Equivalent number of annual cigarette packs
Natural total Irradiation	3	9
Radon	2	6
Cosmic Rays	0.3	0.9
Medical X-rays	0.4	1.2
Public irradiation due to Nuclear reactors	0.0005	0.0015
Average estimated total external irradiation due to Chernobyl in Central Europe	1†	3†
Average estimated total external irradiation due to Chernobyl in Western Europe	0.2†	0.6†

TABLE II
Comparison of allowed doses of irradiation to effects of cigarette smoking

	Maximum allowed dose in millisieverts/year	Equivalent in cigarette packs/year
Professionals	20	60
Public	1	3
Evacuation limit around Chernobyl	5	15

The equivalencies given in tables I and II show that the all-out use of a linear dose-effect relationship applied to low doses contradicts common sense: is it really equivalent that one individual smokes ten thousand cigarette packs or that ten thousand people smoke one pack each?

† **Total dose integrated over 30 years**