Committee I
The Nuclear Option in the Past,
Present and in the Future

DRAFT--6/15/92
For Conference Distribution Only

NUCLEAR ENERGY, PUBLIC PERCEPTION AND POLICY DECISIONS

by

Walter Binner
Deputy Managing Director
Austrian Research Center
Seibersdorf, AUSTRIA

The Nineteenth International Conference on the Unity of the Sciences
Seoul, Korea August 19-26, 1992

Walter Binner

ABSTRACT

May 1992

Nuclear Energy, Public Perception and Policy Decisions

The paper deals with one of today's fundamental conflicts: While there is a rational demand that humankind's stability in respect to its size is secured by a high economic standard and thereby by a sufficient supply of energy, there is at the same time a strong emotional movement for a "simple life" at zero economic growth and with a minimum use of energy. Statistics show, though, that higher energy consumption, which in pluralistic societies allows a decent standard of living, correlates with a decrease in the growth of the population. In this we might see a way to solve the world's most serious problem. In this fact is implied, notwithstanding every effort to avoid wastage of energy, that the total energy consumption of the world has to and will increase. However, there are two substantial obstacles to making that possible: first, the generation of energy as it is achieved presently does harm the environment, in spite of the many remedies already implemented for mitigation; second, there is a lack of public acceptance which originates in the concern about that harm. While it is possible today that a proper energy mix - nuclear power being one of its main constituents - can create a habitat compliant with nature (even with the future increase of demand), public perception, in its simplifying way, tends to move from rational concern to a rejection of any technologically sound solution. The development from a nuclear controversy to an energy controversy to the nostalgic "green" fantasies, combined with a growing mistrust of an impenetrably complex societal structure, show this. Yet, one of the first essentials in a democratic society is to acquire the consent of its citizens to future solutions, and since human beings are rational creatures, too, a way can to be found to do so. Dealing with the nuclear controversy, emphasis in this paper is given to seeking such a consent by pointing out the benefit of nuclear energy, namely its having virtually no adverse impact on the environment in the normal mode of operation. The fact that the risks of nuclear energy (when it is subjected to present day standards of safety) do not surpass those of conventional technologies should eventually overcome public refusal of it. Furthermore, positive statements about nuclear energy by organizations and/or persons who originally and presently still have many objections to its use, affirming that just this nuclear power should still be considered a remedy to the energy problems of today, should be considered a valuable asset to that issue.

Walter Binner

May 1992

Nuclear Energy, Public Perception and Policy Decisions

I. The Problem

Very often these days, in our world in transition, when we observe the threatening menace of a destabilization of the very bases of our life, there arises a nostalgic desire for a return to paradise. The bases I am talking about are the ones of habitat and resources which are endangered by environmental disorders and, most of all, by the seemingly impetuous explosion of the size of our population. Since under these circumstances a life in dignity, welfare and in a clean environment seems to be out of reach, a desire emerges for a simpler way of life, for minimum use of energy and for "zero growth" in all domains of our civilization which ought to make that return to paradise possible. And none of those who would return to the paradise of the past is aware that there are too many of us ever to return and nobody considers that such a paradise most likely never existed anyway (what, then, caused us to leave it in the first place?). Anything blocking that road back, be it technology, a complex societal structure or economical growth, is evil and ought to be rejected. So an attitude has developed, especially in the classic industrial countries, which is counterproductive to any expansion of technological activities and whose backlash into politics is considerable.

I believe that this course backwards - although followed in good faith - can not lead us to that objective aimed at and that to reach that nostalgic simple kind of life can not be undertaken seriously without some more or less coercive measures. The often very forceful and inculpating kind of language of some of their proponents makes me believe that - apart from their determination to impose punitive measures when energy consumption does not drop according to their wishes. I rather believe that the way leading to a stabilized world, with a clean environment, worth living in, with the natural conditions of life maintained and with the globe not overcrowded, can only be followed when technology - and only technology - provides the means for doing so. And, most important of all,

I believe that this can be achieved only by those societies which choose this road by their free and independent will. I shall repeat several times in this paper this most important message: carried out by free, independent societies, chosen by free consent and not depending on any measures of compulsion. This, though, requires political decisions which are closely affected by the romantic and nostalgic trends mentioned before.

With these remarks, the thesis of this paper is outlined. The necessary future political decisions which will be discussed here are dependent on those public sentiments which become so manifest in nuclear referenda and, generally speaking, in all technological referenda and in opinion polls. The fact that the views of the media reflect these sentiments and thereby stimulate the whole process complicates the situation. This paper is aimed at finding ways and means which are helpful in realizing the necessity for further technological development and of ensuring the indispensible public acceptance for it. First I shall now outline the principles and the quantitative impacts of energy in stabilizing the global conditions, its being the main battleground for policy decisions.

II. Energy

It will be shown that with an adequate supply of energy the living conditions of human beings can develop in such a way that the globe remains worth living on, that life can go on in an environment compliant with nature (not necessarily an unchanged nature) and that, most important, there does not necessarily have to be an overpopulation. Above all, though, it is of importance to emphasize that with an adequate supply of energy those processes will take place in free and independent societies, without having to reach out to some social utopia which usually begins with a model of a "new human being" and which often ends with distressing regulations, or even worse, with compulsory measures.

No attempt will be made here to prove this assertion by providing causal connections or theoretical models - to do so down to the last detail would be a difficult enterprise, apart from the

fact that theoretical models require assumptions which from the beginning on are subject to disputations. Besides, if there are a few exceptions - and there are some as will be shown - this would become even more complicated, requiring an undue explanation of considerable length.

I will rather rely upon well-established empirical correlations - which theoretically might be less impressive but which have the very advantage that they state the facts as they are. The only liberty I take afterwards is to interpret them. On that basis the following can be said:

An increasing (a decreasing) consumption of energy correlates with an improving (a deteriorating) economic situation, i. e. with an increasing (a decreasing) per capita gross national product; the latter raises (lowers) public affluence which in turn coincides with an increase (decrease) of life-expectancy and a decrease (increase) of the the excess rates of birth. These correlations, taken from a report by Vossebrecker [1], are demonstrated in sufficient detail in figures 1 and 2 (the abbreviations for all the figures will be explained in the appendix). It is necessary to make the following three points to put these correlations into the right perspective:

1. It has to be stressed that these are empirically stated correlations, not to be mistaken as simple and uncomplicated causal connections; therefore it will not be said that high energy consumption per se guarantees low rates of birth and high life expectancy: rather it can be stated that free and independent societies develop and behave this way. The correlation of high life-expectancy with per capita energy consumption is demonstrated in figure 1, which shows in the right upper corner the highly industrialized countries with the kind of societies mentioned.

2. There are exceptions and deviations from these correlations, as seen in figure 2: some in particular are the Peoples Republic of China (low rates of birth and low gross national product) on the one hand, and Libya and Saudi-Arabia (high rates of birth and high gross national product) on the other. Highly significant, though, is that in both cases one cannot speak of societies that are free and independent in our sense: In my view the Peoples Republic of China is a country of strict communist observance, and Libya and Saudi-Arabia, while belonging to political camps of a different kind, are

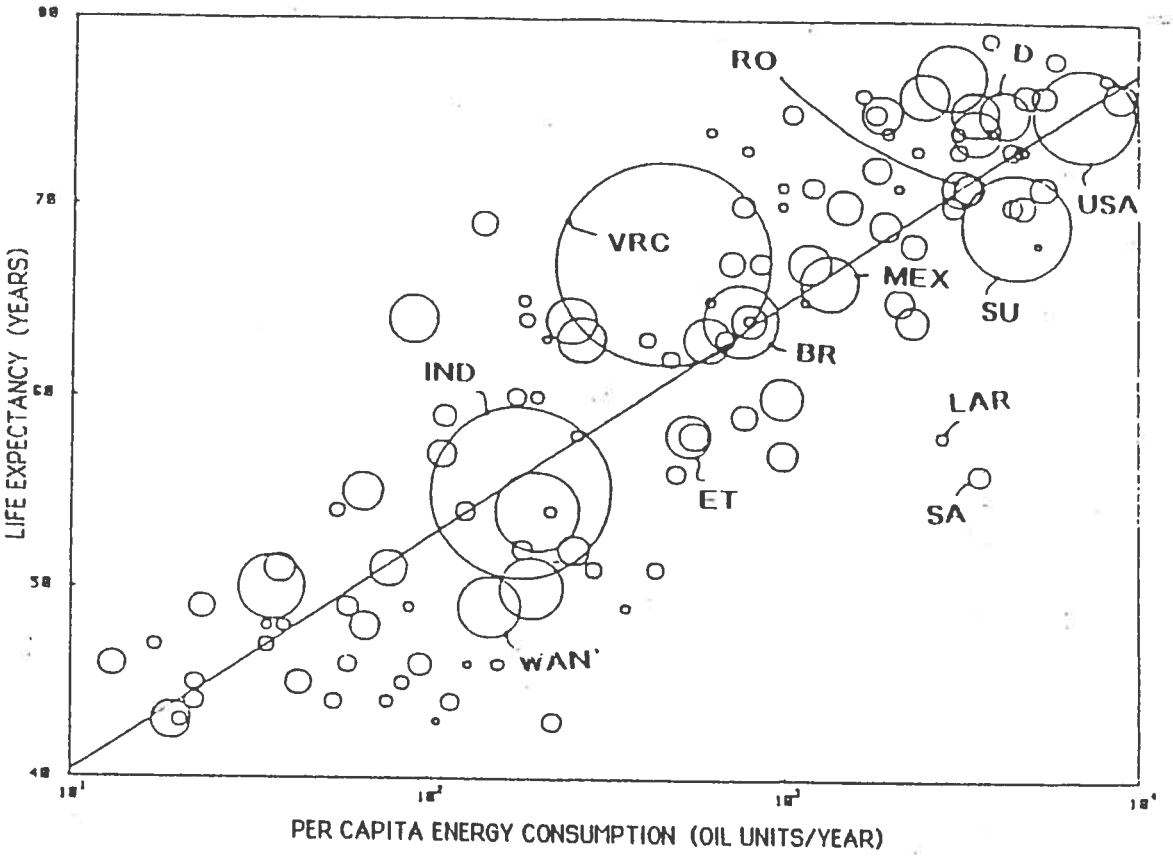

Figure 1: life expectancy vs. per capita energy consumption

fundamentalist societies. In my opinion, however, these very exceptions, in which in contrast to pluralistic societies people move within strict behavioural patterns, prove the general validity of the correlations for free societies.

3. A high consumption of energy is not meant to be synonymous with a careless use of energy. It is well understood that a rational and careful use of energy has to be a leading principle. A good reason for this is the care for the environment and the conservation of natural resources, especially in those countries where up to now the lack of such concerns have led to massive damages to the environment. Yet, even by using all possible methods of energy conservation, the use of energy in the industrialized nations will stay high compared to that in the developing countries and will be essential for a high standard of living. Taking into account the logarithmic scale of these pictures, one can imagine that even a substantial reduction of the energy consumption in the highly

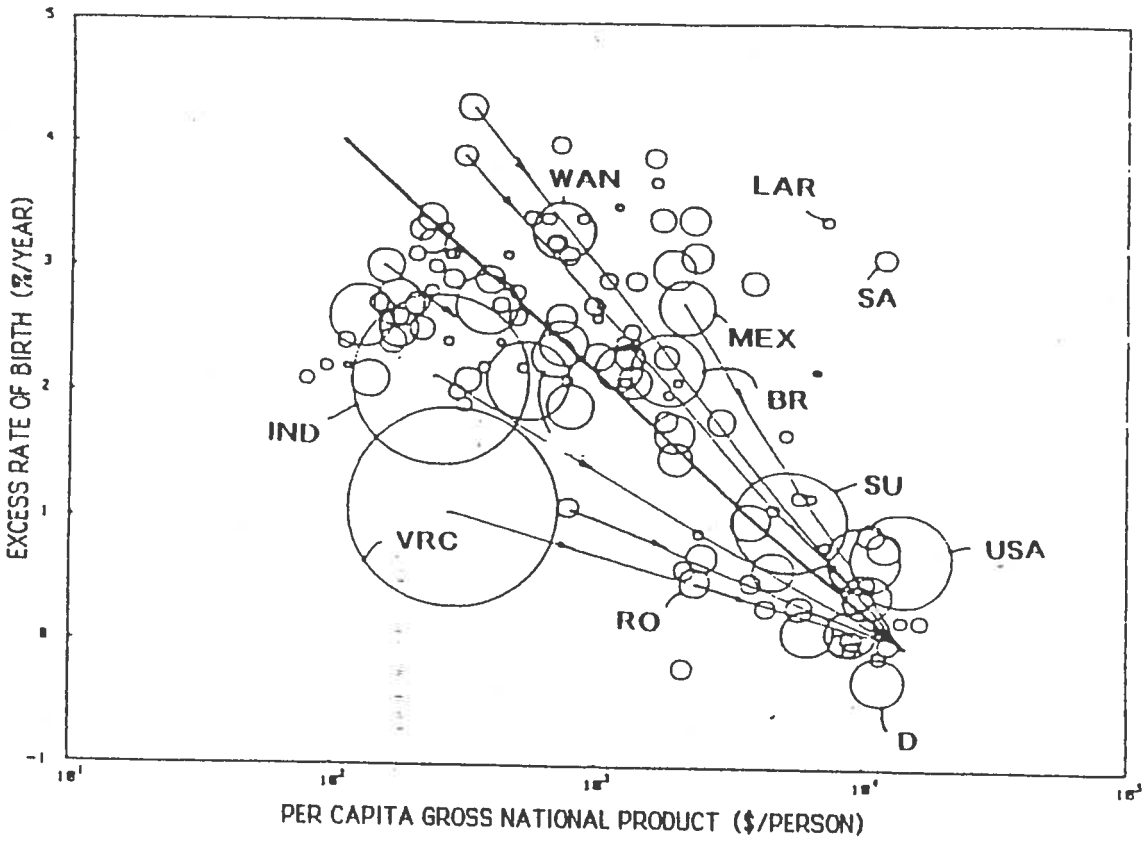

Figure 2: excess rate of birth vs. per capita gross national product
(Arrows indicate possible trends in the future)

industrialized countries of, let us say, 20 % would be represented by a minor shift of the graphs to the left and leave the general statements unchanged.

Let me now move to the correlation most important in the context of the subject of this meeting, i. e. the direct correlation of energy consumption and excess rates of birth. While Vossebrecker derived his correlations from data printed in the Fischer Weltalmanach 1987 [2], I, in order to assess this independently and because of the time elapsed since then, took the data from Fischer Weltalmanach 1992 [3]. The observation period is the 9th decade of our century. In a simplified manner one can express this correlation in the following way:

<u>High consumption of energy correlates with low excess rates of birth,</u>

<u>Low consumption of energy correlates with high excess rates of birth.</u>

This correlation will now be demonstrated in the following figures for all 128 countries of the world with more than one million inhabitants, each averaged over the period 1980 - 1989 (the area of the circles representing the various states are proportional to the size of their population; their excess rates of birth are given by the ordinates of the centers of the circles while the abscissas represent the per capita consumption of energy in the year 1989). I have to make the following points about these graphs:

1. In general, figure 3 shows that there is a trend to lower excess rates of birth with increasing per capita energy consumption. The trends in the various states or group of states is best shown in this figure depicting the OECD states, the former and present communist countries, the Islamic States and developing countries (for the abbreviations of the names of the states I again refer to the appendix). Exceptions in the general trend shown in that graph are the Islamic States which

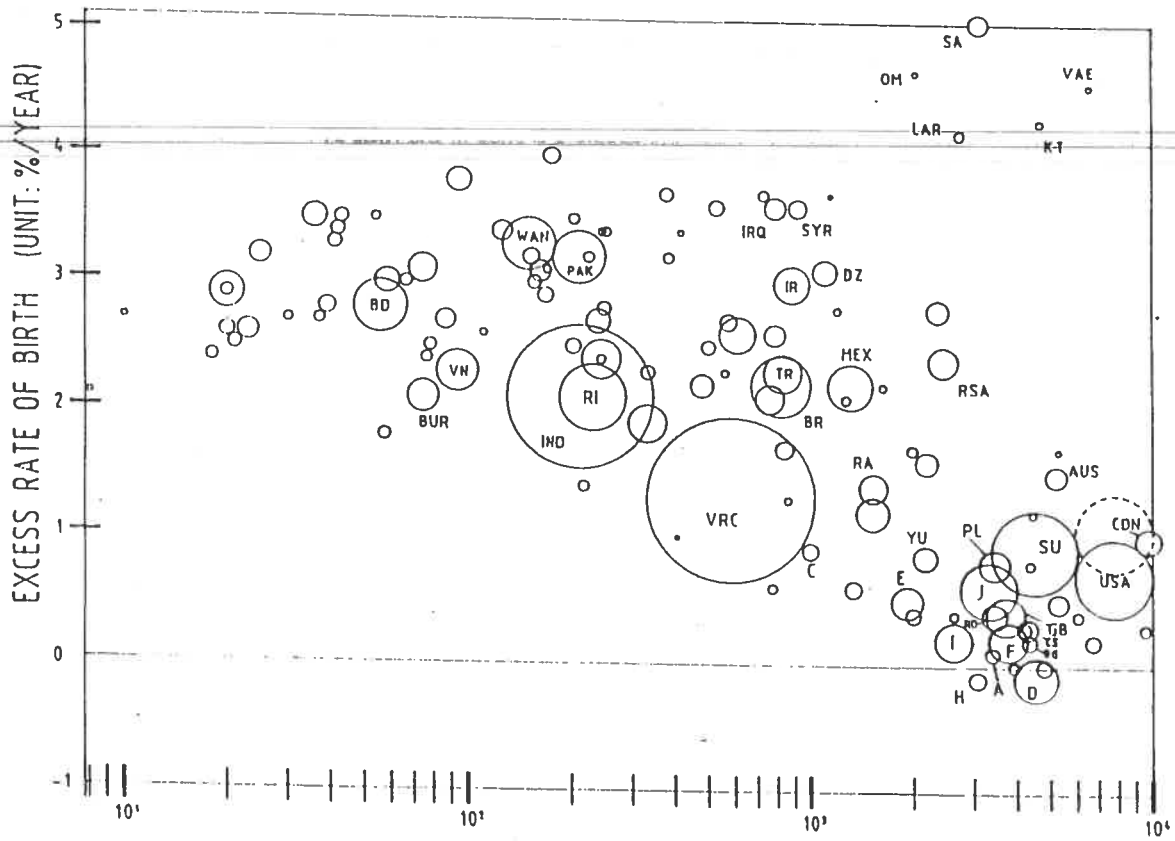

Figure 3: excess rate of birth vs. per capita energy consumption

show a strong increase in population (excess rates of birth) in spite of their high values of energy usage. As mentioned before, these states consist of fundamentalist societies in a more or less strict sense and by that are therefore, I believe, not representative of the behaviour of pluralistic societies. I consider this a strong evidence for the validity of the assumption that it is these societies which lead under the provision of sufficient supply of energy to a stabilization of the size of their population.

2. The underlined statements in the text above and figure 3 are expressed in terms of excess rates of birth (for which the asserted correlations hold), but the ordinates in figure 3 are drawn for the growth of population (which also includes immigrants/emigrants). So the two are not the same, yet for our purpose this is a conservative approach, because movements of immigration go from poor to wealthy countries. The real figures for the excess rates of birth in the latter are therefore even smaller than in the figure shown while in the poor countries the reverse is true; the trends in the underlined statements are therefore even stronger than demonstrated in the figures. As a confirmation of that one can observe the growth of the population in the United states (dotted circle) - after subtracting the number of immigrants in the 10-years time of observation (roughly 7,3 million people) the solid circle represents the excess rate of births in that country.

3. The country designated as SU is now the Commonwealth of Independent States (CIS), in which strong movements of population might occur. Yet the graph can still be assumed to be representative of the CIS, because such movements would be mainly internal ones and, if at all, have started only since the end of the observation period.

4. As stated before, the effects of the rationalized use of energy will not distort the general validity of the message of that graphic representation, because any rationally justifiable reduction of energy consumption in the industrialized countries is represented in the figure as a slight shift to the left. This can easily be visualized by the shifts the 10 % reduction in the annual per capita energy consumption in North America and the 7 % reduction in Western Europe from 1980 to 1989

would assume in that figure. It would be quite different, though, if that reduction would take on a greater order of magnitude.

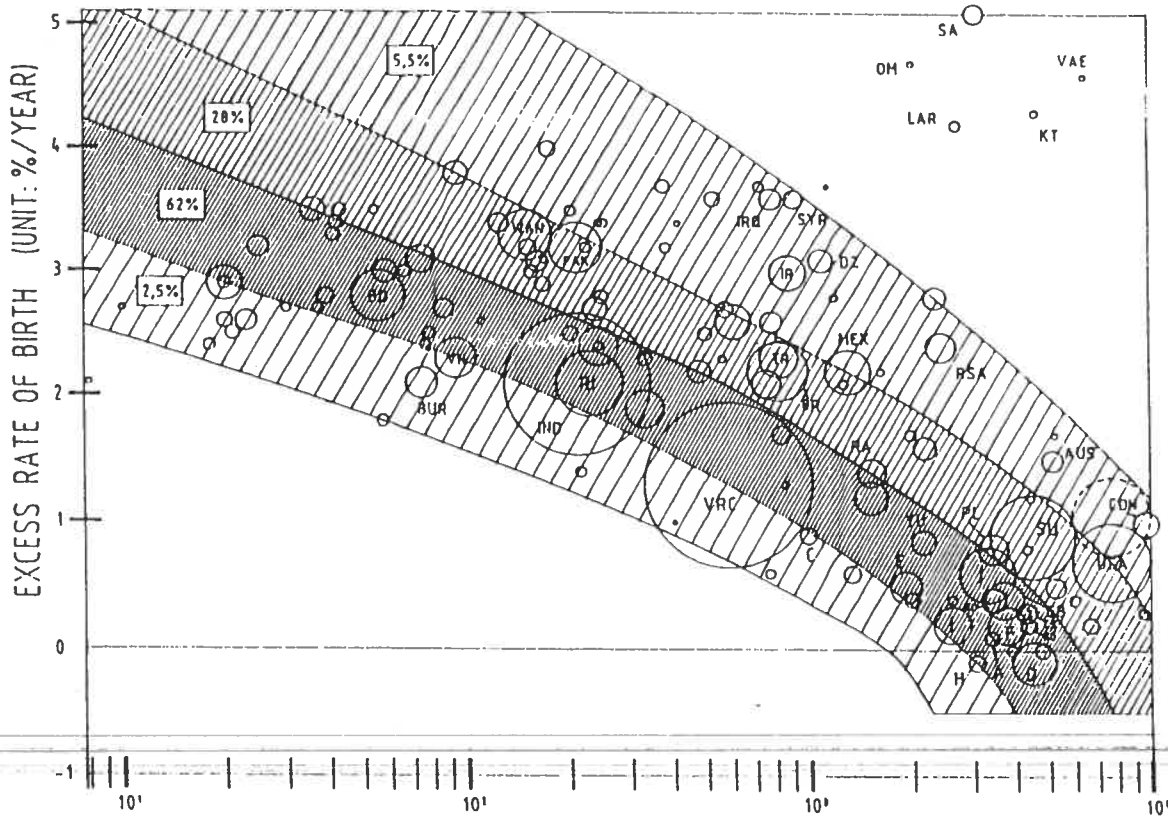

Figure 4: excess rate of birth vs. per capita energy consumption
(Representation by shaded areas)

5. The trends of the correlation birth rates/energy consumption are better represented in figure 4, which is a different representation of the same conditions as shown before. Here the various shaded areas represent, as indicated, the percentage of the world population for which the specified correlation holds. Please note the "empty" triangle-shaped area in this figure, in which virtually no country shows up below a certain value of the ratio of (birth rate)/(energy consumption). Having higher birth rates at lower values of the energy consumption is in my view an indication that, in poverty stricken countries, the lower their living standard the faster their population grows. We have to realize that practically all of our goods and the overwhelming

productivity in our agriculture are deeply dependent on the allocation of enough energy. So anything which goes beyond a very careful reduction in our consumption of energy, which must be limited to the saving of waste energy and to the improving of the efficiency of the appliances only, will inevitably carry us into that domain.

Taking note of these remarks, one can drew the following conclusion: In general, increasing consumption of energy correlates with the decreasing growth of population; in industrialized countries with a higher consumption of energy there is even a stronger tendency to decreasing excess rates of birth, the quantity which eventually is responsible for the size of the population on this globe. It is also shown that the birth rate is even stagnating or becoming negative in some of the highest industrialized societies.

So a free, independent and pluralistic society, while sufficiently securing its material basis - which includes the adequate supply of energy - is in the position to meet the global requirements for a stabilized level of population, combined with the personal benefits of a decent standard of living and a sufficiently high lifespan.

All of this is nothing but the quantified and refined statement of the well known and well experienced fact of life that citizens being in the position to achieve prosperity and caring about the welfare of their offspring simply see to it that their families are limited in size; so the better off they are, the fewer children they have.

III. Environment

With these thoughts in mind, it seems to me that it is now our duty to see that the standard of living in the developing countries is raised as swiftly as possible in order to enable them, if they wish to do so, to develop their own societies similar to those in the industrialized countries, into free, pluralistic societies which give them the chance to avoid overpopulation. Yet there is another

duty, briefly mentioned initially, to which we have to focus our attention now:

Next to the globe being not overcrowded, attention must be given to keeping the habitat worth living in. It seems to me that the solution to the problem of environmental damage is given when energy technologies are used whose impact on the environment, caused by pollutants, stays well within the bandwidth of the variation of those substances as produced by nature alone and to which humanity has been accustumed forever - and I mean this locally as well as globally. These technologies, then, would not alter the living conditions of human beings to an extent which would go beyond their exposure to pollutants at naturally given levels.

Today the by far predominant share of energy supplied worldwide is produced by chemical combustion of fossil fuels, be this oil, natural gas, coal, wood, and be they used in their original form (e. g. coal) or refined form (e. g. gasoline); and the by far overwhelming majority of pollutants stem from these processes. There is a wide range of such pollutants - SO2, NOx, CO, CO2, dioxin, carbohydrates, heavy metals, dust, benzpyrenes, soot, aerosols of all kinds, even radioactivity in a diminutive amount - a list which almost seems inexhaustible. Though many of these pollutants up to now have been, to a greater or lesser degree, successfully reduced in the environment, they cannot be completely eliminated. They pose problems in dealing with their end-products, and many of them have an extraordinary longevity, and some have not even been dealt with at all.

Usually the impact of these chemical pollutants, when exceeding their naturally given bandwidth, has to be quantified and limited according to whichever of the following considerations is more conservative:

1) what will be adverse to the health of human beings, to the wealth of the species populating the globe and to the preservation of the environment; or

2) the current state of the art of technology.

This leads to rather complicated limits on the permanent, and temporary, impact of these substances according to emissions and immissions, which are - depending on the state of the art of

the technology and of our knowledge - subject to permanent changes.

Nowadays the concern focusses increasingly around the emission of carbon dioxide, CO_2, which is widely considered not a pollutant but rather as the final combustion product of carbon, produced at a rate of about 3 kg per 1 kg carbon burned. This CO_2 ist the most significant of the greenhouse gases, being responsible for a slow warming of the atmosphere of the globe. In spite of many theoretical models predicting quite varied rates of this warming, there is evidence supplied by air samples up to 160000 years old which were taken from iceprobes from the arctic regions; they show that during warm climatic conditions on our planet there was a CO_2-concentration in the atmosphere of 260 to 280 ppm, in cold times one of 190 to 200. Today the figures became more dramatic: In 1750 we had 280 ppm, in 1958 there were 315 ppm, and today there are 350 ppm [4]. Evidently the short period of time these high concentrations have existed has not yet resulted in a measurable warming-up effect, probably mainly because of the large heat capacity of the oceans and of the land masses. This leads me to believe that there still is a chance to counteract the global warming effect because the half-life of CO_2 remaining in the atmosphere is on the order of roughly 100 years. Yet the present rate of increase of more than 4 % of the CO_2-content in the atmosphere per decade urges us that it is time to do something.

The search for pollution-free energy systems, therefore, has become predominant and much hope has been placed, though much less success has been achieved, in the development of so-called renewable energies, i. e. solar energy, wind, geothermal energy, biomass, and also wood. With biomass, it seems to me irresponsible that soil should be used to produce energy and not food desperately needed in a world of hunger; and wood combustion is all but clean. But all of these renewables suffer from the fact that they have low energy density, so an additional concentration process is necessary when usage in major energy grids is mandatory (we later come back to the question of decentralization), and that concentration process is expensive - for everyone. A general and widespread increase in prices would be a deep economic shock to the public, with its negative

consequence on the whole economy. One just has to think back to the effects the oilprice shocks had on the public.

So, although renewable energies are a fully justifiable approach to ease the energy situation, one has to realize that their applicability is limited, except for hydropower, to a very small fraction of the users of energy. Promises are very often given, on the other hand, that they might replace the other forms of energy on a global scale, but, even if they might offer the solutions for the day after tomorrow, they fail to be the solutions for tomorrow, and we are in bad need of those.

On a large (global) scale the only successful renewable energy is hydro power (sometimes neatly wrapped up as solar power, which, actually, is not wrong) - but I am living in a hydropower country, and I have experience with public resistance to that form of energy, which is understandable enough for those who have to give up homes and property for a new power plant or its reservoir. Also, hydropower worldwide covers only a small percentage of the demand for energy, and it is locally dependent.

The advocates of renewable energies are the ones who usually oppose nuclear energy, but one has to realize that nuclear energy is a form of energy which technically is well developed and in a permanent process of improvement, it offers abundant resources, and does not alter the environment when operated in a way fulfilling the present day safety requirements. So, let me turn to that.

IV. Nuclear energy

Some organizations and persons which up to now have strictly opposed nuclear energy or were rather reserved about its application have recently taken a more open stance to it (which probably did not earn them much praise from more militant adversaries). I refer here to the Club of Rome, to the Union of Concerned Scientists, to the American Medical Society, to Professor Mayer-Abich (later, I will quote some of their statements), just to mention a few. This does not mean they have given up their principle objections against nuclear energy, but they also see the main advantage it

has in the present global energy situation.

Nuclear energy in its normal, safe mode of operation keeps the globe free of chemical pollutants, and it releases radioactive effluents only in such an amount that this does not alter the bandwidth of the natural radiological burden to the public. I exclude here, for the time being, the professional personnel who are directly involved in the energy-producing process, i. e. personnel in nuclear power plants, in uranium mines, in the fuel cycle, or also in other professions which have to do with radiation and where the radiological burden might go beyond the range of the natural burden. In this case risk assessment has to consider possible effects beyond that range - as, for example, is done in the ICRP-recommendations, which recently have lowered the limits of the permissible exposure for professional persons. Nothing, though, has changed for the general public. For it the burden stays, as was said before, within the natural limits and this will remain so also when there is a high number of nuclear installations on the globe, corresponding to the world's needs for energy.

Expressing this in our everyday language, and this ought to be the message to the public, we can say that the normal operation of nuclear power plants, including their fuel cycle, causes virtually no toxic burden to the public and no danger of global warming to the environment. The only burden, quantitatively expressed as the radiological dose, stays completely within the bandwidth of the dose caused by natural radiation and does not increase it.

An example might illustrate this: In Austria the external natural dose varies from 20 to 200 mrem/yr (0,2 to 2 mSv/yr) and the background at the site of the nuclear power plant is 70 mrem/yr (0,7 mSv/yr). Its operation would have caused an additional burden of less than 1 mrem/yr (0,01mSv/yr) 2 km east of the plant, and this would have rapidly decreased with increasing distance from the plant. A analogous assessment can be made for the internal dose.

Of course, this is an advantage in times when other energy sources which are available on a major scale pose severe pollution problems just by their normal operation. This is the reason why people usually opposing nuclear energy express their cautious view that one should not discount this

very advantage of that form of energy.

We have now to focus our attention on the risks of nuclear energy, the perception of which is the main reason for lack of public confidence. Even when there is agreement that this risk (in its definition as the product of severity and probability of an accident) is small vis à vis the risk posed by other technologies, the perception of the severity of a nuclear event seems to be so high in the public's mind that no matter how small the likelihood of its occurrence, people are reluctant to use this kind of energy. Therefore, we have to look now into the realistic risks associated with severe accidents, the misuse of nuclear material and the long term consequences of the possible leakage of radioisotopes.

Considering severe accidents, Chernobyl comes first into one's mind. In those power stations as well as in other ones of the same RBMK-type, energy is produced - in my view - not in nuclear reactors but in nuclear devices, to put it bluntly. This is a strong statement, but I want to justify it right away. Their huge reactor cores are practically assemblies of loosely coupled autonomous nuclear regions (and therefore dependent on a very complex control philosophy), with a positive void coefficient of reactivity and a tendency to exhibit thermohydraulic instabilities in the coolant channels, with a very tangled flux shape - especially in the case of Xenon-poisoning - and with the potential of an initially positive reactivity ramp in case of shut down: how can one describe this machine differently than by using the expression nuclear device? And these are already the fundamental differences from the reactors with present day safety standards. Their reactor cores are quite different: compact, stable, self-limiting, with fast acting shut-down systems and negative reactivity ramps over the whole range. The accident at Chernobyl was clearly initiated by a super-prompt critical excursion, and this very event, due to inherent physical properties, cannot occur in reactors with state-of-the-art safety standards. Additionally the Chernobyl-type plants are poorly engineered, with an inadequate defense in depth, with very slow moving control rods, with a reactor protection system which can be bypassed - and <u>all</u> of that contributed to the accident.

The consequence was, as stated, a super-prompt critical excursion - a huge expolosion, in simple terms - which blew out radioactive substances into the free atmosphere, subsequently followed for 11 days by practically uninhibited release of more of those substances before the dumping of various materials into the zone of destruction became effective on the 12th day after the accident. Today's assessment of the fission product releases state that 40 to 57 % of I131, 15 to 53 % of Cs137 (updated Soviet estimate is 26 %) and - of course - 100 % of the noble gases escaped into the environment [4]. This puts that accident into the most drastic release categories PWR 1 to 3 and BWR 1 to 3 of the WASH-1400 analysis [5] or in the highest release categories 2 and (phenomenologically) 1 of the German Risk Study for Nuclear Power Plants [6]. In simple words: This was virtually the worst case scenario in respect to the release of radioactive material.

The consequences: In view of what one can definitely register up to now in respect of harming human life and health there were 31 fatalities, most of them by radiation, and about 300 persons suffering early radiation illness who are recovered now (not taking into account the possible late consequences of cancer). Considering the late effects, the most in-depth study up to now was performed under the auspicies of the International Atomic Energy Agency with the cooperation of 6 International Organizations, 25 States and 200 scientists, undertaken from February 1990 to March 1991 [7]. For the sake of the completeness of this paper its conclusions concerning late health effects is here presented:

General Conclusions

> There were significant non-radiation-related health disorders in the population of both surveyed contaminated and surveyed control settlements studied under the Project, but no health disorders that could be attributed directly to radiation exposure. The accident had substantial negative psychological consequences in terms of anxiety and stress due to the continuing and high levels of uncertainty, the occurrence of which extended beyond the contaminated areas of concern.
>
> The official data that were examined did not indicate a marked increase in the incidence of leukaemia or cancers. However, the data were not detailed enough to exclude the possibility of an increase in the incidence of some tumor types. Reported absorbed thyroid dose estimates in children are such that there may be a statistically detectable increase in the incidence of thyroid tumors in the future.

> On the basis of doses estimated by the Project and currently accepted radiation risk estimates, future increase over the natural incidents of cancer or hereditary effects would be difficult to discern, even with large and well-designed long term epidemological studies*).

Contentions that there were already thousands of victims of leukemia or other forms of cancer do not seem to be valid in the view of that report, although future investigations will certainly be pursued. As up to now the consequences to human life and health are very serious but in the same order of magnitude as those caused by "conventional" accidents which occurred before and were not necessarily considered cataclysmic ones, the environmental consequences, however, broke the dimensions of previous events: to have such a large area of land rendered uninhabitable for many generations must not happen again.

A comparison to the dramatic events of Three Mile Island comes to mind: there a reactor of today's safety standard - briefly defined before as having a selfstabilizing reactor core and an adequate defense in depth - experienced a core-melt accident in which also substantial amounts of activity were released from the nuclear fuel but which, in their vast majority, were contained within the second and the third safety barriers (the pressure boundary and the containment) and absorbed by the various structural equipments and materials. The accident occurred due to a series of operator errors, but the plant confinement was virtually kept intact despite continuing operator errors throughout the whole accident - a forgiving machine as it was called in one report. From the nuclear fuel 8,6 to 16 % of I131, 11 to 13 % of Cs137 and again practically 100 % of the noble gases were released [8], but apart from the noble gases (which were in this case of no radiological significance) virtually nothing escaped to the environment (only about 15 curies of I131, that is about 0,00002 % of its inventory): The consequences were no loss of human life, no harm to health (apart from nervous disorders), no contaminated environment. For completeness, there ought to be

*) The statistically detectable increase of thyroid tumors might be of the order of 25 cases above the natural occurrence of 35 fatal thyroid cancers among the children of the roughly 120000 evacuees around Chernobyl, as was mentioned during the presentation of the results of the study.

added that since then many efforts have been undertaken to avoid such operational mistakes in the future: by easily surveyed control rooms, by better training, and so on.

I am aware of the fact that it is a much better safety philosophy to avoid accidents in the first place than to accept them and then to mitigate their consequences – my mentioning here the two most serious ones should not be taken as an indication that this is not the case: to both principles – avoidance and mitigation – there is given the same attention within the whole area of nuclear safety, but this short paper simply does not offer room enough to do the same in greater detail.

Let me here go on to the next area of concern: the misuse of nuclear material. This would be a serious threat in the hands of politically unstable regimes, but it would also be the most awkward, namely an expensive and technically most difficult way, to try to conduct it over a nuclear power program, especially one which is based on the use of power plants with light water reactors. Consider here, for example, that the threat of the Iraq having the bomb soon was most serious, even though the country had no nuclear power plant, while Germany, on the other hand, with its technically most advanced nuclear power program, has no weapons production. Plutonium from a nuclear power plant with a light water reactor is, due to the high rate of spontaneous fission of the large fraction of Pu240, most unsuitable for the design of a nuclear device – and alone the fact that under the administration of President Carter such a device was designed just to see if it works (and eventually it did work) indicates that the technical difficulties thereby can only be overcome by a highly developed weapons industry.

Another fact corresponding to this is that the safeguards inspection system installed within the International Atomic Energy Agency to ensure that a nuclear power program is in accordance with the obligations of the Non-Proliferation Treaty is technically quite effective, while a clandestine program just for the development of nuclear weapons, bypassing that treaty and a nuclear power program, is very hard to discover, as the case of Iraq shows. Probably the safeguards system ought to be extended into the political domain, because the decisive actions to pursue a weapons program are

taken in this area.

Nuclear waste: One and a half billion years ago in today's African state of Gabon a natural nuclear fission reaction, such as in a modern nuclear reactor, went on for about 150000 years, thereby producing the energy of what today two big reactors would produce during their life-time (this fission reaction was possible because at that time the isotopic composition of uranium was what we call in present terms enriched, and the fuel spent in the reaction was replaced by fresh uranium carried down by the nearby river). The reaction produced, of course, also the eqivalent amount of fission products and of actinides, so it is possible today to see what happened to them in all the time since then. Roughly spoken, this occurred: nature successfully managed to store as much as 10 tons of fission products in the ground; nearly all the heavy elements and most of the fission products have remained in place over that period of time [9]. And all this in spite of the fact that the site where these substances emerged from the fission process was not a waste repository in today's sense and the waste was not conditioned as we would do it now.

Conditioned waste today consists mainly of Sr90 and Cs137 (being the fission products with the longest half-lifes of about 30 years each) and of the rest of half to one percent of the actinides, mainly Plutonium. Its radiotoxicity is initially determined by Sr90 and Cs137, and therefore attenuates by a factor of 1000 every 10 half-lifes, that is, every 300 years, and it reaches the radiotoxicity of the host material, if this were an old uranium mine, after about 1000 years. So an encapsulation would, in this case, not have to be static for eternity but dynamic in the respect that it does not deteriorate before these 1000 years are over - and this can technically be achieved. That, and the knowledge we gained from Oklo ought to be assurance that the waste problem can be solved satisfactorily. Of course one has to consider many things, like the aquifers, to find the right host ground for repositories ans many more things. But consider this: if the migrating effect were so efficient in the underground, how could there still be, after hundreds of millions of years, deposits of high concentrations of various materials?

Let me now give the following résumé: By going into more detail in this chapter I have tried to show that the real risks of a carefully administered program of nuclear energy in its most adverse potential for severe accidents, in its waste problem, and in the domain of misuse of nuclear material, differ greatly from the perceived risks by groups of the public. Its severity is comparable to the risks of other categories of technology, even being surpassed by the most severe "conventional" accidents, like Bhopal or Longarone – and therefore the risks are in reality reduced from the so often feared cataclysmic consequences into the range of "normal" technology.

V. The nuclear controversy

I have often experienced that while trying to convince people of the safety of nuclear energy (and since I am a professionel in that field and believe in it, I always take great pains in explaining things as I see them) the effect was sometimes rather counterproductive (and this might even occur with some readers of this last paragraph). One day I took a high official of our country out to our nuclear power plant, and to make best use of the one-hour ride to the site I explained the safety-precautions and -installations to him during that time. Getting out of the car, he suddenly said : "Up to now I had no appreciation of nuclear energy, but now, after you tell me all of that, I am really afraid of it". While I tried to explain that the real probability of an event with unparalleled consequences is close to zero (it is not exactly zero because this holds only for phenomena which would contradict natural laws), an image formed in his mind telling him that because of all the considerations given to safety concerns, the probability of an accident surely must be closer to one than to zero.

On the other hand, when we do not explain – and many are tempted not to do so because of the same experience – then the objections turn out to be even worse, and one might get accused of evading the truth. But I think this is the worst way one can choose. I believe the real dilemma lies not in the choice between explaining and not explaining. I believe the problem lies somewhere else: it occurs to

me that the very facts justifying the existence of nuclear energy, namely its benefits, have not yet been presented in the proper way. For the acceptance of nuclear energy in this world it is of no relevance that it is a fascinating technology which inspires its community of experts. This would leave it in the exclusive domain of that community - but nuclear energy cannot be an end in and of itself. Its justification rests completely in its benefits to the globe, insofar, as mentioned already, as it keeps it free of chemical pollutants and releases radioactive effluents only in such an amount that they scarcely alter (by an undetectible quantity) for the public the burden of natural radiation. This holds even when there are a high number of nuclear installations in operation which would help to meet the energy needs of the world. (It is worthwhile in this context to point out that nuclear energy from fission processes does not increase the globe's radioactive inventory. It rather reduces it by converting one species of radioactive nuclei of very long life [uranium, thorium] into two of a comparatively short decay time, so that a net result looks like this: for 100 vanishing uranium nuclei less than 10 cesium or strontium nuclei emerged, also short-living vis á vis uranium, in addition to actinides, the most important of which is plutonium. These add up to less than or - in breeders - slightly more than 100 nuclei, but also of much shorter half life than uranium).

Expressing in our everyday language these benefits of nuclear energy - and this is the message to the public - we can say that the operation of nuclear power plants, including its fuel cycle, causes virtually no toxic burden to the public or to the environment.

Yet all this has up to now scarcely been brought into the debate - instead of it only the negative aspects were communicated to the public. We saw that there were no adverse consequences of Three Mile Island on life, health and environment, but it was a disaster in perception and communication. Chernobyl was a major accident harming health and life, though in this respect with consequences which have been surpassed by many "conventional" accidents, yet of unprecedented consequences to the environment - but in view of the differences in technology and in the physical principles, Chernobyl cannot be considered as a valid indication of the performance of nuclear energy operating

under modern safety standards.

And also here the public concern was less directed to what did happen than to what could or might one day happen. Furthermore, with Chernobyl there are now assertions that there might be thousands or tens of thousands of late fatalities which might not show up due to the lack of statistical significance. This opens the door for quite subjective interpretation. One can then also say, and in my view with more justification, that when no changes in the general trend can be detected, then no such changes exist.

Fears projected into the future; a complex societal system which is not transparent to the individual anymore; the misuse of insider knowledge for personal profit which cannot be controlled anymore by the public - all these circumstances cause irrational feelings of helplessness which seek relief. Today such relief might come from fighting technology, specifically nuclear technology, because in the first place it offers a rational cause - namely the possibility of an accident doing harm to the public and the remembrance of the first appearance of nuclear technology as atomic bombs; and in the second place it offers the irrational satisfaction that the public can now control in this way that unintelligible societal structure and its misuse. And that fight, especially if it is successful, gives the public the feeling that it might regain the control it is so desperately looking for.

A few problems make a dialogue in this controversial subject even more complicated. This is not intended to be an exhaustive listing, but just an indication of the many problems that exist:

- We use different languages: Where we speak of an event occurring with "a probability of 10^{-6}/year", the often quoted man in the street says in his everyday language "never"; and this might not be wrong because in the period of time he is looking at, namely his, his children's and his parent's lifespan together, which are in the order of 10^2 years, the event most likely "never" occurs. A compromise between both expressions, though, looks awkward when it is expressed as "with a probability on the verge of certainty that that specific event will not occur".

- The role of the media - literally the mediators - is in areas of public controversy not always

that of mediators but of amplifiers of fixed opinions, usually those of their readers, listeners or watchers. After all, the consumers secure the existence and the profit of the media and the media are attuned to their language.

- Due to the partly irrational nature of the conflict, strict logical argumentation is not the strong point of the opponents to nuclear energy, but that is not required: a collapsed bridge or an accident with dioxin are taken as examples for the dangers of nuclear energy. It is often heard that more energy is used for the construction of than there is extracted from a nuclear power plant, and that owners exhibit complete commercial clumsiness (because nuclear plants are the most expensive to build and because of their many defects they stand still all the time), there are even cows with two heads near plants and so on ...

- Some members of certain groups of the population might be very susceptible to rejecting nuclear energy, because of their specific beliefs or anxieties. The community of the opponents is often strangely influenced by ideologies and spreads messages of salvation, and it offers a home for people with extreme ideologies who today might otherwise become homeless.

A case in point, which reveals the dynamics of the problem, might be given here from my personal experience. At the end of 1978, after the completion of the first (and only) Austrian nuclear power plant, the former Chancellor of the Republic of Austria, in order to get over a deadlock in the parliamentary debate, decided to link the start-up of the plant with the outcome of a public referendum which he himself wished to succeed. He did so knowing that the opinion polls at that time showed a solid 60 : 40 lead in favor of nuclear energy. Two weeks prior to the referendum he had the unfortunate idea to declare in public that the (expected) majority should be seen to be a proof of his successful governmental politics - and promptly the referendum failed by the close result of 49,7 : 50,3. At once, he himself transformed into an opponent of nuclear energy and a law was passed in parliament forbidding its use in Austria; subsequently the trend of rejection leaped over to other

areas of technology, amplified by a political movement which herein saw its chances for expanding its power base and by the enhanced belief of the population that power plants and industry are dangerous because they create chemical pollutants and alter the environment. This trend of rejection was originally not intended, it turned out that way: today in Austria it is extremely difficult, if not impossible, to pursue technical enterprises in the following areas: nuclear power plants (of course), fossil-fired power plants, hydropower plants (low head and storage), high voltage transmission lines, factories (chemical, semiconductors), highways, railroad tunnels, waste treatment installations, waste repositories, tall buildings, even the organization of a world exhibition, and so on. In spite of a substantial improvement in reducing the emissions of chemical pollutants (the harm of which would have been really dramatically reduced by the use of nuclear energy), the anti-technological trend continues and accelerates.

VI. The Energy Controversy

Two things now come into play which make a successful campaign against nuclear energy not the end of a struggle, but rather a starting point of the continuation of the campaign into the domain of energy (and technology). Therefore every society is well advised to look carefully into the situation whether she uses nuclear energy or not.

First, as was shown in the Austrian example, encouraged by the successful campaign against nuclear energy, such a movement will not be content with a single and isolated success only, but will spread its activities into other technological domains. This becomes clear when we look at the internal mechanisms of mass movements: They deal with the public domain, use its language, get the attention of the media, organize campaigns - and thereby build up the tools, the structure, the goals and the ideology of a successful political movement. Active and younger people seek a field for political activity and understand the chances they can find there for their ambitions. So the

movement forms a political party. Haunted by the success of this new party, the older, established ones, in order not to loose their voters, drift into the same path. The vehicle for this development is the anti-technological sentiment, having been so successful in its first campaign, the anti-nuclear campaign.

Secondly, a technical dilemma arises by phasing out nuclear energy: this does not reduce the pollution to the environment - on the contrary, it amplifies it, as might be concluded from the preceeding comments. There are now four ways to cope with that situation:

1. To continue with the existing conventional technologies and remove from them the pollutants: This is possible to a large extent (let us say 80 or 90 %), at the expense of reducing the efficiency and the economy. But the rest of the pollutants remains airborne, the waste products also cause environmental problems and, worst of all, removal is not possible at all for carbon dioxide, which by its property as a greenhouse gas is considered today as the main problem of all. Its content in the atmosphere increases even faster when nuclear energy is no option anymore.

2. To develop new forms of energy: renewables which produce no pollutants - like solar, wind, geothermal, or which have a zero-balance (of consumption and release of carbon dioxide) - like biomass. Except for hydropower, which, though, is not a newly discovered form of energy but was used already long ago, and which has adverse and publicly opposed effects to the landscape, all of them suffer from low energy density, which makes the prospect for their large scale use in the future look rather dim.

3. To shrink the use of energy overall: Since 1. and 2 also suffer increasingly from lack of public acceptance (the secondary consequences of the nuclear controversy), this solution is now the top philosophy of many environmentalists. This can and should be accepted as long as it means improving the efficiency (by reducing waste energy, as for example with well considered co-generation, or with better-designed appliances), but it can easily become counterproductive when it interferes with the requirements for a healthy development of society.

4. To impose a new tax for electricity under the context of fighting CO2-emission: for example 14 g/kWh (corresponds roughly to 1,2 cents/kWh) for coal, 13 g/kWh for oil, 12 g/kWh for natural gas and 7 g/kWh for hydro (one wonders what hydro has to do with CO2: therefore, it is in this case called an "energy tax"). This is a proposal by the Green Party in Austria, and it is interesting to see where the money is supposed to go: 60 % should go into the state retirement funds, 30 % should support socially weak persons and ailing industries and 10 % should go into the resarch for renewable energy. This is what I called initially a punitive measure: it is primarily not intended to find solutions for alternative energy but to be a coercive measure punishing the use of energy.

The energy tax looks like nothing but an energy-cutting program at all costs. When one looks into some of the ideas and proposals of these programs one sees that some of them evidently suffer badly from a lack of expertise, because they are simply extrapolations far beyond the narrow range of applicability. Here are some examples:

1. Small co-generation units are proposed today because of their supposed high efficiency. They only exhibit this efficiency when their electricity and heat output both assume optimized values - which can be achieved only when they are connected to an existing powerful, i. e. permissive, grid, or when the demand exactly fits the supply (This, for example, can be the case in hospitals which need an almost constant supply of heat - for laundries, disinfection, etc. - and where the variation in electricity demand is caught up by a central grid). This limits the efficient applicability of these small units to a small fraction of demand only.

2. Decentralized systems, based on small co-generation units, look attractive only when one believes that small is really beautiful; they theoretically produce for the same amount of demand the same amount of pollutants, but in practice more than a centralized system would. Yet, even more important, they lead to much stronger immissions, since they have to be sited near the customers; this is counterproductive to the principles of environmental protection.

3. It is not lack of interest in energy conservation when electricity demand does increase

overproportionally to the total energy demand; this fact, which is the universal experience, is based on the following reason: increase in demand for electricity rather serves the principle of energy saving by being a substitution energy, so that a small increase in the use of electricity saves a much bigger amount in primary energy, thereby having a net saving effect. Furthermore, future higher demands for this most valuable form of energy are to be expected in households, in electro-cars and in electrically operated heat pumps, just to name a few. All these will increase the overall demand. All the efforts to increase the efficiency of appliances cannot counteract the increase in demand completely. Forced shrinkage of total energy consumption and of electricity consumption at the same time will lead, in my view, to a collapse of the energy system.

4. Major consumers of electricity (motors, motor pumps, electrolyses, process heat) cannot rely on a flock of small decentralized suppliers because they depend on the stability of the grid. Also, the reserves necessary for decentralized islands must be provided by major grids because of their higher degree of reliabiliy.

So when digging quantitatively into these problems, it turns out that decentralized suppliers can serve only a small proportion of the users. Ideas advocating this, when presented uncritically to the innocent public and offered to politicians as being the path of least resistance in terms of acceptability, in combination with the fact that planning and building for the future demand of energy takes a preparation of many years, might impose severe problems in securing the energy needed for the future.

VII. What can we do?

The picture I have tried to present is nearing completion.

It is high time that energy, being indepensible for the production of all of our goods and of our food, and vital for the stabilization of the globe's population, being one of the most fundamental of today's problems, is again to be administered by competent people and handled by policy decisions

which are based on courage, knowledge and determination.

Coming full circle, and seeking for help as I do so, I will allow myself to find support by quoting, where appropriate, the opinions of renowned persons and/or institutions; in doing so I will try to see that these quotations will not be in violation of the broader context in which they were originally presented.

The world-renowned philosopher of sciences, Karl R. Popper, at the occasion of an interview with Der Spiegel, expresses the view [10] (translated):

> Underlying the ecological catastrophies is the explosion of the population, which we have to resolve in an ethical way. There must be only wish-children born.

At the same occasion, when asked on what his lack of sympathy with the "green" (environmentalist) movement is based, he gave the answer (translated):

> Because of their foolish hostility against science and technology. There is an irrational core within the Greens. This leads to just the opposite of what they pretend they want. Besides that, they crave for power themselves and are the same hypocrites as those they claim they are opposed to.

Popper is an optimist, but there are also pessimistic views, as the one expressed by Herbert Oruhl, one of todays ecological forerunners [10] (translated):

> The most devilish problem ..... is the increase of the population. Beyond that, with every species, the explosive growth ends with wide-spread dying off. ..... The remaining chance consists only in the prolongation of the time allowed.

Whether now seen in a pessimistic or in an optimistic light, the real problem, that of the population explosion, is recognized. We have given much attention to what energy means in respect to this problem, and we want to state again that this is not the remedy in and of itself but a necessary ingredient for solving it in a democratic society where general consensus exists. It also can be deducted that while the industrialized states must take every effort to avoid energy being wasted, the total energy consumption of human society will and has to grow.

It is imperative that the production of energy must not lead to a defective habitat. This requirement is all the more urgent when we see that as a consequence of the presently growing

population, and with the necessity to improve the living conditions in the developing countries, there will be more energy needed in the future then there is needed now. Conservation of energy and avoiding the waste of energy are necessary but this all will only have a slowing effect on the overall increase in energy demand.

All this has to be realized and kept in mind when dealing with the energy controversy (the nuclear controversy is now but only a part of it). The philosophy of the "green" proponents is - radically expressed - to shrink the usage of energy at all costs because that seems to them the only way to keep the enviroment clean.

I hope that the correlations here presented have shown clearly and convincingly the interdependence of energy and population growth - also when taking into consideration an efficient conservation program. Securing the energy basis is vital, and requires knowledge and competence. In dealing with the public in the energy controversy one has clearly to recognize that, a) it is possible to convincingly show that energy is necessary for the prosperity of a democratic, stable, limited and self-regulating society, and that, b) the energy needs can be provided for by available technologies which keep the globe clean (or - in some areas, which restore it to a clean condition). In the course of this process one will inevitably come to nuclear energy - but for many it will take a long time to do so. In that case, at least intermediate solutions can be offered which lie along way: replacing, for example, an old brown coal fired power plant with a modern gas combined cycle would reduce the CO2-output per electrical kWh from 1,20 kg to 0,40 kg.

I now return to the nuclear controversy. As stated before, chemical pollutants and greenhouse gases cause, or most likely cause, adverse effects to the environment. While the pollutants (SO_2, NOx, dust, CO, ...) can be removed to a large degree, this is not possible with the greenhouse gases, mainly CO_2, the most important of them. The remedy here is to avoid their formation.

The content of CO_2 in the earth's atmosphere presently rises by 0.5 %/year, the annual rate of its emission is 22 billion tons per year [11]. We have seen that the use of nuclear energy is one

of the most important remedies to this problem. Presently, the use of nuclear energy saves the globe about 2,5 billion tons of CO_2 per year; if all the fossil fired power plants were replaced by nuclear power plants this would save the globe another 8 billion tons per year (deducted from [3][11]). The rest of the build up comes from all the other uses of combustion, like heating, traffic, industry. If in those applications there is an appropriate substitution by electricity, then the reduction could be driven down much further. At this moment, this ought to be considered only an assessment of the order of magnitude.

I have tried to show that nuclear energy, including its fuel cycle, when subjected to safety standards at the present state of the art, does meet the requirements of a safe technology (to express this qualitatively, its risks are smaller than or comparative to that of other energy producing technologies of major importance). It seems to be fitting to express here some of the views of organizations or persons I mentioned before, who had and still have substantial objections to nuclear energy.

The Club of Rome, which has been strongly against the use of nuclear energy from the beginning on, states in its report of 1991, "The Global Revolution" [12] (translated):

> " ..... Today we admit reluctantly that the combustion of coal and oil, due to the carbon dioxide emitted in that process, is most likely more dangerous to human society than nuclear energy.
> Therefore there are valid reasons to keep the nuclear option open and to develop fast breeder reactors. Yet, we have to point out that this option will stay a partial solution. In the short time available for the reduction of the CO_2-content, it might be most unlikely that the efforts be undertaken and the necessary means be raised to build a sufficient number of nuclear power plants. ....."

To the last remark one ought to reply that by today's powerful industrial potential it was possible to build, in roughly 30 years, the 350 nuclear power plants producing now, in 1990, about 20 % of the worlds electricity [2]. France alone, by her indigenous industry, pursued a nuclear power program which after only 20 years provides 75 % of her electricity supply. The Club of Rome, by the way, regrets the use of oil for combustion (and the same holds for natural gas) instead of keeping

it as a reserve for the production of medicines, plastics, paints and so on.

Professor Mayer-Abich of Germany, who is a critic of nuclear energy and who participated in the so-called Enquete Kommission dealing with energy scenarios, one of which foresaw its phasing out of nuclear power, now takes the following position [13] (translated):

> Immediate phasing out (of nuclear energy) would mean that the emissions of carbon dioxide would increse. With that we would back away from the self-imposed dangers of atomic energy by exposing other countries to another danger, that of global warming.

The Union of Concerned Scientists of the United States, of the opponents to nuclear energy most likely the one with the highest professional expertise, states as of January 31, 1990 [14]:

> " ..... The United States bears a special responsibiliy to provide leadership in the prevention of global-warming. .....
> The United States should develop and implement a new National Energy Policy, based on the need to substantially reduce the emission of carbon dioxide while sustaining economical growth.
> .....
> The policy should include :
> .....
> 4. A nuclear energy program that emphasizes protection of public health and safety, resolution of the problem of radioactive waste disposal, and stringent safeguards against the proliferation of nuclear material and technology that can be applied to weapons construction. ....

The American Medical Association, while not explicitly opposed to nuclear energy but concerned with the health problems of radioactivity, states in its 1988 report [15]:

> An advisory committee of physicians and other scientists, on behalf of the Council of Scientific Affairs, reviewed the role of nuclear energy in generating electricity. The Council concurs with the committee's conclusions and recommendations presented below, and recommends that they be adopted as a statement of policy on the health and safety aspects .....:
> .....
> 4. Safety of nuclear power - Generating electricity with nuclear power is a safe method in the U. S., both absolutely and in comparison with alternative methods. .....

It seems to me that these quotations of persons and organizations which very often expressed their doubts on the use of nuclear energy put the many assertions which associate nuclear energy with dangers unparalleled before in technology into the right perspective: the risks of nuclear energy

with modern safety standards are those of a proven and well established technology, comparative to the risks of conventional technologies, and not higher.

The advantages, though, are such that this technology is an important remedy for the consequences of pollutants and emissions of greenhouse gases caused by many other technologies.

VIII. Conclusions

The paper summarizes the position energy has in the process of stabilizing the world's population in a democratic way, as well as the possible adverse impacts energy production might have on the environment, and the ways to avoid them (which - at the moment - are based among others on the use of nuclear energy). It shows the influence romantic and nostalgic ideas have on the public attitude towards energy, especially in some of the highest industrialized countries, an influence which finds its climax in the nuclear controversy and subsequently is followed by the energy controversy (or, more generally, by the technology controversy). Those anti-technology sentiments are based to a large extent on idealistic views. Although lacking a sound rational basis, they might (in the process of attempting to impose an unrealistic social structure) rely on coercive measures. It might not be too far-fetched to be reminded of the words word of Ralf Dahrendorf, from a discussion of the future of Social Democracy with the present Austrian Chancellor [16] (translated):

> Those who were on the search for a complete new world, who tried to realize this complete new world, arrived as a rule at a dictatorship.

Certainly this will find the protest of many good-willed environmentalists, but I believe it is justified to point out in such a drastic way that possibility to them and to those who are called upon to prepare and to implement policy decisions, which should be based on the following:

1. Energy is an indispensible ingredient in keeping stable the size of the population, which cannot be controlled by enforced regulations but can be limited only (and therefore expected to be

permanently in control) by the free consent of a democratic, pluralistic society. The mechanism for that lies in a simple correlation: The better off people are, the more considered they are in their family planning (they have only wish-children). In more technical terms: The higher the gross national product - which, among other things, is based on a sufficient amount of energy - the smaller the excess birthrate.

2. An adequate supply of energy for the production of goods and for the provision of food must be made available with technologies based on principles for the preservation of the environment. Such technologies exist, one of the most important of them being nuclear energy. Their use, combined with other measures, such as conservation technologies, can be sufficient for centuries to come. This gives us time to develop methods for energy production for the distant future without causing irreparable damage to the environment.

3. To secure such a development, policy decisions are necessary, mainly in the area of convincing a hesitant or even frightened public. The politician leading that way should be that rare kind of person who understands both the rational way into the future and how to deal convincingly with the irrational in humankind.

References

[1] Heinz Vossebrecker: Energie und Zukunft (Energy and future), Fakten und Gedanken zu einer Überlebensfrage, März 1987,

[2] Fischer Weltalmanach 1987, Fischer Tachenbuch Verlag, Frankfurt/Main,

[3] Fischer Weltalmanach 1992, Fischer Tachenbuch Verlag, Frankfurt/Main,

[4] S .A .Khan: The Chernobyl Source Term, A Critical Review; Nuclear Safety, Vol. 31-3, Jul. - Sep. 1990,

[5] Rector Safety Study (Rasmussen Report); United States Nuclear Regulatory Commission, WASH-1400 (NUREG-75/014), October 1975,

[6] Deutsche Risikostudie Kernkraftwerke; Bundesministerium für Forschung und Technologie, Bonn 1979,

[7] The International Chernobyl Project; International Atomic Energy Agency, 1991,

[8] TMI Analyses of Coolant Samples by SRL, ORNL, B&W, Bettis as of 3/30/79 and 4/11/79,

[9] The Oklo Phenomenon; International Atomic Energy Agency, Proceedings of a Symposium, 23 - 27 June 1975,

[10] Der Spiegel 13/1992,

[11] Die Zeit, Nr. 19, 1. Mai 1992,

[12] SVA-Bulletin, Nr. 20/1991,

[13] SVA-Bulletin, Nr. 12/1990,

[14] Siemens Argumente Nr. 78, 27.02.90,

[15] Report on the Council of Scientific Affairs, Report 0 (1-88),

[16] Zukunft, Nr. 8, August 1990.

Abbreviation of States

A	Austria
AUS	Australia
BD	Bangladesh
BG	Bulgaria
BR	Brazil
BUR	Myanmar
C	Cuba
CDN	Canada
CS	Czecho-Slovakia
D	Germany
DZ	Algeria
E	Spain
ET	Egypt
F	France
GB	Great Britain
H	Hungary
IND	India
IR	Ireland
IRQ	Iraq
J	Japan
KT	Kuwait
LAR	Libya
MEX	Mexico
OM	Oman
PAK	Pakistan
PL	Poland
RA	Argentina
RI	Indonesia
RO	Romania
RSA	Central African Republic
SA	Saudi-Arabia
SU	Commonwealth of Independent States, former Soviet-Union
SYR	Syria
TR	Turkey
USA	United States of America
VAE	United Arab Emirates
VN	Vietnam
VRC	Peoples Republic of China
WAN	Nigeria
YU	Yugoslavia