TRYING TO HELP THE ENVIRONMENT – MORE ON THE WEST UKRAINE CASE

C. Marchetti
International Institute for Applied Systems Analysis,
Laxenburg, Austria

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C. MARCHETTI
International Institute for Applied Systems Analysis, Laxenburg, Austria

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Abstract—The Hydrogen Economy can be seen as a train ready to move. We should start building the track. In this paper we examine a combination of technologies and circumstances that make large scale water splitting using nuclear heat from HTR reactors an attractive proposition. The idea is to tap a large natural gas pipeline system near an area where oil tertiary recovery pays for the consumption of large amounts of CO_2. The high value that CO_2 can command is shown by the construction by Shell of long pipelines to carry CO_2 from a natural field to an oil province. Natural gas is steam reformed to H_2 and CO_2 using heat from HTR nuclear reactors with a process developed at KFA Jülich in Germany. The oil province to receive the CO_2 is in West Ukraine where three gas pipelines converge to transport Soviet gas into Western Europe. One of the critics to the original suggestion made at the Moscow Hydrogen Conference in 1988 was that the massive use of reactors (up to 30 GWth) was made improbable by public opinion rejecting nuclear energy wholesale. A study we made for the European Community in the meantime, and whose pertinent results are reported here, shows that the doldrums of nuclear energy are not related to public opinion as such but to the stop-go mechanisms of the economy related to the Kondratiev long cycle. We will try to show that the broad scale evolution of the system will open a "window of opportunity" for this project during the next 10 years.

The central dogma of our hyperactive and voluntaristic Western society is that when a problem comes you better solve it. Through action and not through retreat. In that spirit we did propose in Moscow in 1988 a pilot experiment to start solving the CO_2 greenhouse effect in case it exists. Or for fun and profit, in case it does not.

The idea is very simple. Where the Russian gas pipelines converge to enter Europe via Czechoslovakia, carrying about 50 GW of natural gas, we implant a *gas refinery*, steam reforming methane to H_2 and CO_2. Luckily, nearby there is a belt of old oil fields that could easily and *profitably* take the CO_2 for tertiary extraction of perhaps 100–200 million of tons of oil, and for final storage of CO_2.

The energy for reforming, in the endothermic process, may or may not come from 30 GW of High Temperature Reactors. Fifty to sixty per cent of this power will finally find its way into product hydrogen and can be considered a form of *open cycle thermochemical watersplitting*. Basic blocks can start at a couple of GW thermal, and H_2 can be mixed into the stream of natural gas or sold straight.

The environment is a global object and if we want to influence it positively, we must think in global terms, especially in what concerns size. World energy consumption is now about 10 TW (10^{10} tons coal equivalent/year). The Russian pipeline is 50 GW plus 15–20 GW from the reactors (as H_2). By adding pumping stations the final capacity can double, and the reforming will bring the total to about 140 GW or 1% of the world primary energy consumption about 2005.

One per cent is a significant level for a start. To give a reference, the interesting Canada–Germany project, with its 100 MW, is one thousandth of 1% of world energy consumption, insignificant from the ecological point of view. Another point in favor of the West Ukraine proposal is that the technology is 100% available. The plant, however, is two orders of magnitude larger than any reforming plant in operation, and this can be a golden opportunity for breakthroughs in processes and equipment.

Since 1988 the critics concentrated on a formal point, that our charts are somehow obscure, and a very substantial one that nuclear energy is gone, due to the robust green opposition. The first question can be solved with a three minute lecture on Darwinian diffusion of cultural frames. The second requires a more sophisticated approach and will represent the substance of our presentation. The central message is that: *opposition to new technology has no influence on quantities but on qualities, and that stopping of nuclear construction has to be related to Kondratiev long waves in economics.*

Most of our systems analysis is based on the idea that our actions are explications of cultural frames diffusing epidemologically into subsets of the social system. Independently of hierarchical levels, in a fractal spirit. The diffusion of an epidemics is represented in Fig. 1. The number of people catching it first increases because

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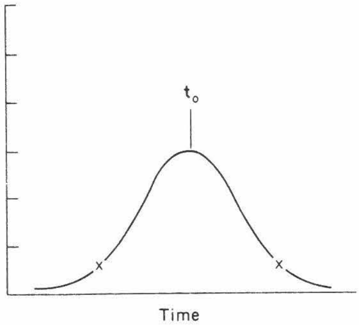

Fig. 1. The chart represents the rate of spreading of an infection in an epidemological diffusion process. The infectable gets it from the infected, and the rate grows exponentially at the beginning, with the number of infected. It reduces halfway when the pool of infectable is rapidly reduced.

of the number of infected–infecting ones, and then decreases because of the exhaustion of the infectable ones. The shape resembles a Gaussian but it is not. The variable is time, anyway.

If we cumulate the infected ones we get a logistic. In Fig. 2 it is normalized with the saturation point taken equal to unity. Bent curves are clumsy when put together in the same chart, so we usually present the logistic in the Fisher–Pry transform that straightens the tails (Fig. 3). We can see this representation at work in Fig. 4 where it plots the number of deaths in 1665 London plague as reported in Defoe's book. The number in parenthesis, 54,700, gives the saturation point, i.e. the total number of deaths; the ΔT of 8.5 months gives the speed of the process (time to go from 10% to 90% of the deaths) and May is the central point positioning the process in time.

Attack by *Pasteurella pestis* can lead a common citizen to death. Attack by the *green* cultural frame can lead PMs to spin legislation. The formal identity of the two processes is neatly shown in Fig. 5 where the cumulative number of ecological laws is reported for the U.K. The central point is in 1977, so we are now past its prime and

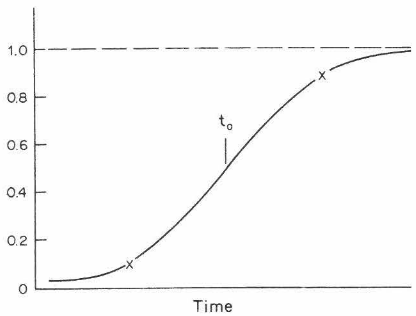

Fig. 2. Integrating the rate of infection of Fig. 1 we get a logistic equation, here *normalized* taking the pool of infectable as equal to unity.

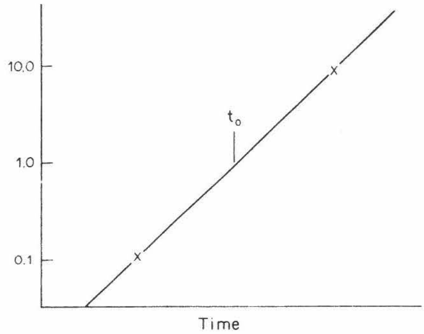

Fig. 3. Straight curves are more handy to check and compare. The normalized logistic of Fig. 2 has been straightened by taking $\log(F/1-F)$ where F is the fractional number of the infected ones and $1-F$ that of the remaining infectable. Taken this way the log does not compress the chart, it expands the tails, helping precise matching with the empirical data.

a ΔT of 35 years shows the process covers a full Kondratiev cycle. The present one did actually start in 1940.

The situation is much more the same if we look at international conventions on environment as reported in Fig. 6. In both cases the saturation (>90%) lies in this decade (1990–2000). We have looked at a bunch of states, reaching basically the same result. The only important difference is in the level of saturation, i.e. the final number of laws, but this can only be due to different legislative style. A notation of methodology: when the saturation point has not been reached, as in the cases of Fig. 7, it can be calculated by iterative best fitting of the data, the saturation point being the free parameter.

Scientists are part of the system just as legislators and they behave much the same way. The cumulative number of papers on CO_2 and climate as reported by ISI (International Scientific Index) fits perfectly the cultural wave paradigm (Fig. 8). ISI picks only the top layer of scientific magazines and this may explain the relatively low saturation point (1400). Although this wave is somehow late by respect to the legislative one (centerpoint only in 1984), the saturation point is again into the next decade.

The penetration of nuclear energy in West Germany, indexed by GW connected to grid looks almost identical, saturating in the nineties and with the centerpoint in 1983 (Fig. 9). Its remarkable smoothness in no way transpires the waves of opposition that raged in the meantime. This is typical of all new technologies we have examined so far. From railways to electricity, to cars, to water fluoridation. What the opposition seems to gain in fact is a better matching of the new technologies to society, in terms of safety, comfort and unobtrusiveness. Seen from this angle, opposition is a healthy and finally constructive operation. Germany is not a special case and smoothness is not the prerogative of its discipline. Social systems are more ordered than we think, as shown

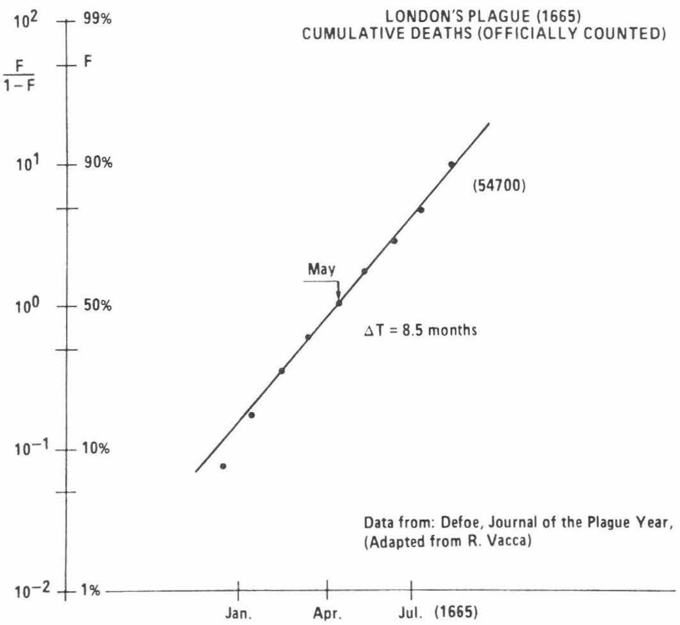

Fig. 4. Although the spreading mechanism postulated for Fig. 1 is very rudimentary, it provides an excellent match for many actual cases, here the pest in London (1665), as described by the number of deaths, cumulative. The logistic equation seems to provide an excellent description for the diffusion of cultural frames. We have analysed more than 3000 cases taken from the areas of economy and sociology.

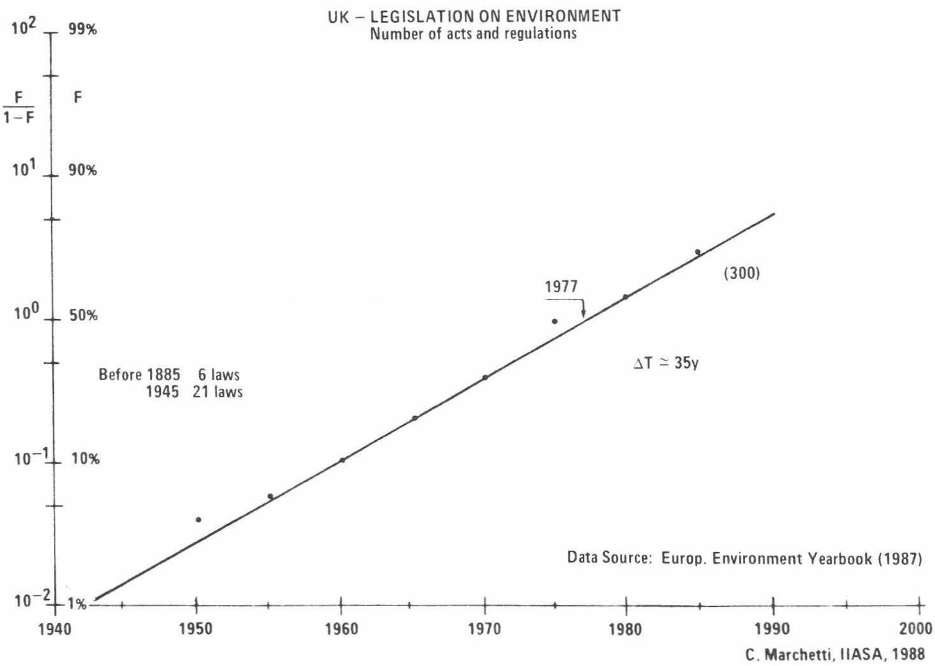

Fig. 5. When the idea that the environment is important spreads into the heads of MP, they react by producing legislation. The pulse is here very well described by a single logistic. The laws appear to saturate to 300 for the U.K.

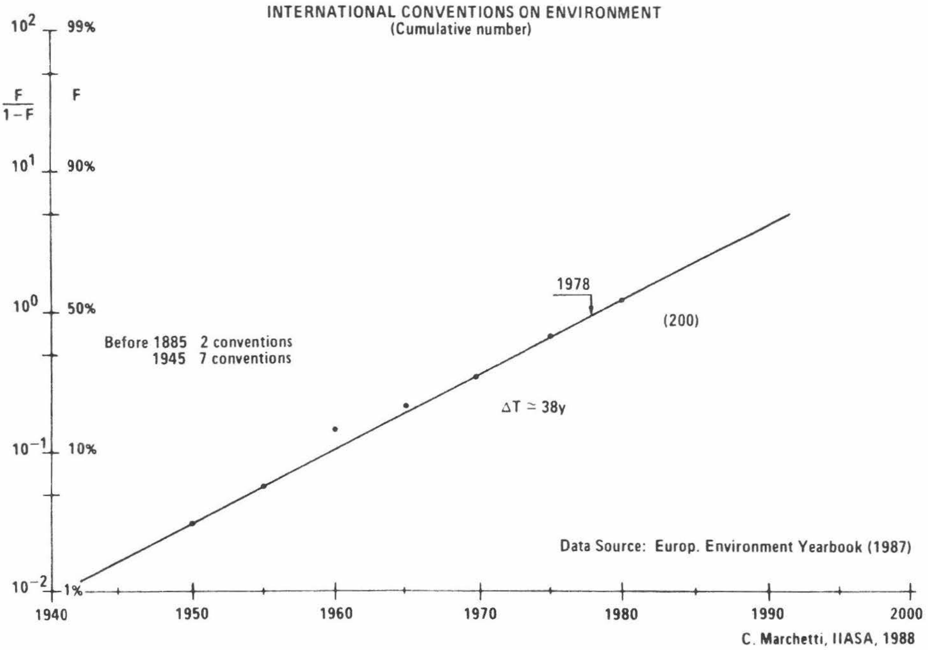

Fig. 6. As for Fig. 5, but for international conventions.

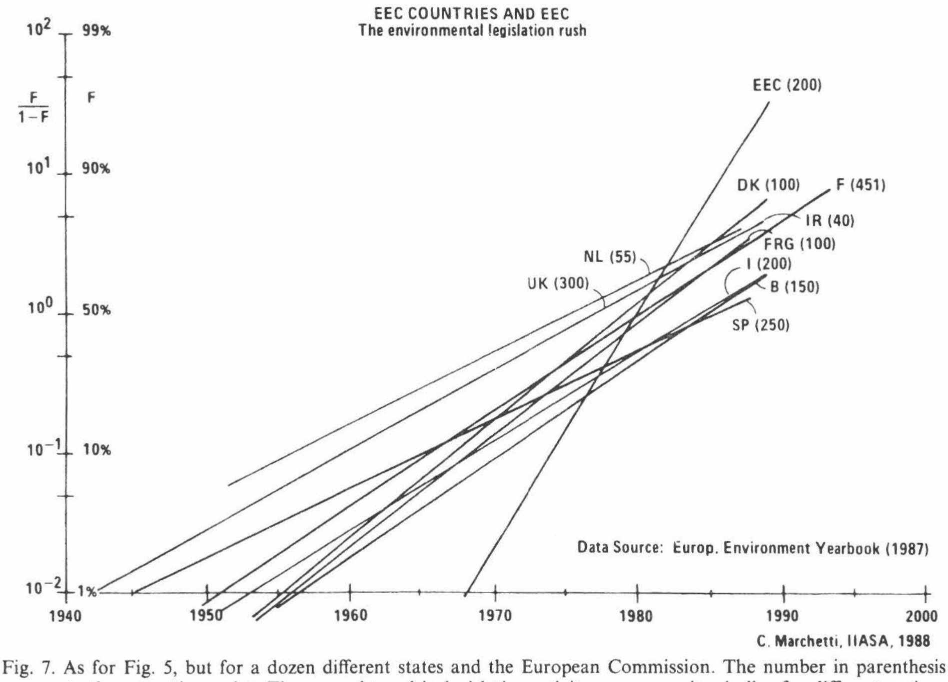

Fig. 7. As for Fig. 5, but for a dozen different states and the European Commission. The number in parenthesis represents the saturation point. The general trend in legislative activity appears quite similar for different nations in this normalized representation except for EEC.

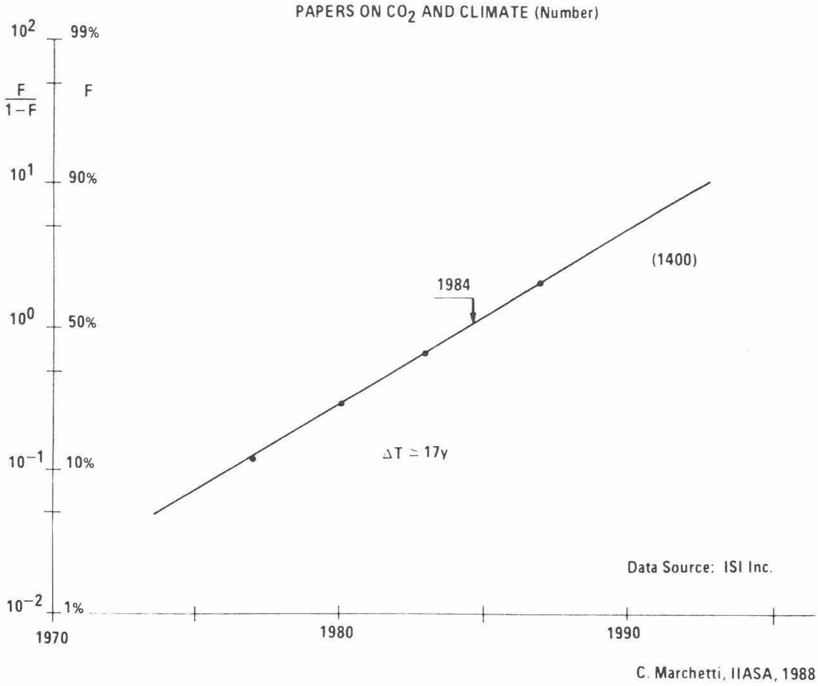

Fig. 8. Scientists are a subset of the social system and do not escape its rule. They react to the spreading of a cultural frame by producing papers. In this case on the importance of CO_2 for climate. The set is not complete because ISI samples top level publications only.

in Fig. 10 reporting nuclear penetration in most of Western states. In all cases a single go saturating in the nineties describes the facts. The only exception is for the U.S.A. where accurate fitting shows *two* waves of nuclear construction (Fig. 11). We will use it to have a more articulated picture of the interaction between the nuclear and the media taken as a proxi of public opinion.

The model of cultural epidemics must be applicable also in case of a sequence in time of diffusion starts, and the very worn out but still quintessential chart of Fig. 12 reports the case of primary energy sources at world level. New competitors displace old ones which bend down in terms of market shares and finally disappear. This representation so faithful over more than a century, is mathematically very thrifty as only two parameters are assigned to each equation. It permits forecasting and backcasting over short data bases, the length depending only on data noise.

The time constants for penetration are in the order of 100 years. No improvisations in the area of primary energies. The future 50 years appear to belong to natural gas *and* nuclear energy. The swiggle for nuclear is most probably due to the fact that it sells *en gros* to the already existing electric distribution net. A similar situation occurred for natural gas for areas where city gas grids existed already. As the time constants of penetration slowly decrease from a source to the next we may expect a value of about 80 years for nuclear. *This penetration is too slow for taking care of* CO_2. We must then resort to "amplifying" measures like the one we proposed in Moscow. There with one unit of nuclear energy we eliminate the CO_2-equivalent of three units of natural gas.

Another interesting chart can be constructed using the information in Fig. 12. Taking a weighted amount for the H/C ratio in each primary fuel we can calculate the mean H/C ratio for the mix of fuels at any given time. The result is reported in Fig. 13 and can be formally interpreted as a competition between H and C. The ratio for chemical fuels cannot go beyond 4, and this is why the curve bends, starting the next decade. If we assume the secular equation actually represents the evolution of *quality* demand by the system, the only way to keep it going beyond the value of 4 is to introduce "*external*" hydrogen produced by watersplitting with a non-fossil fuel primary energy, i.e. nuclear or solar.

Let us now come back to the installation of nuclear power plants and try to gain some insight into the time structure of opposition and the meshing with the construction and operation activity. This will prepare us for the last step of showing why nuclear energy construction has saturated now with the last stations committed in the seventies and eighties being connected to the grid.

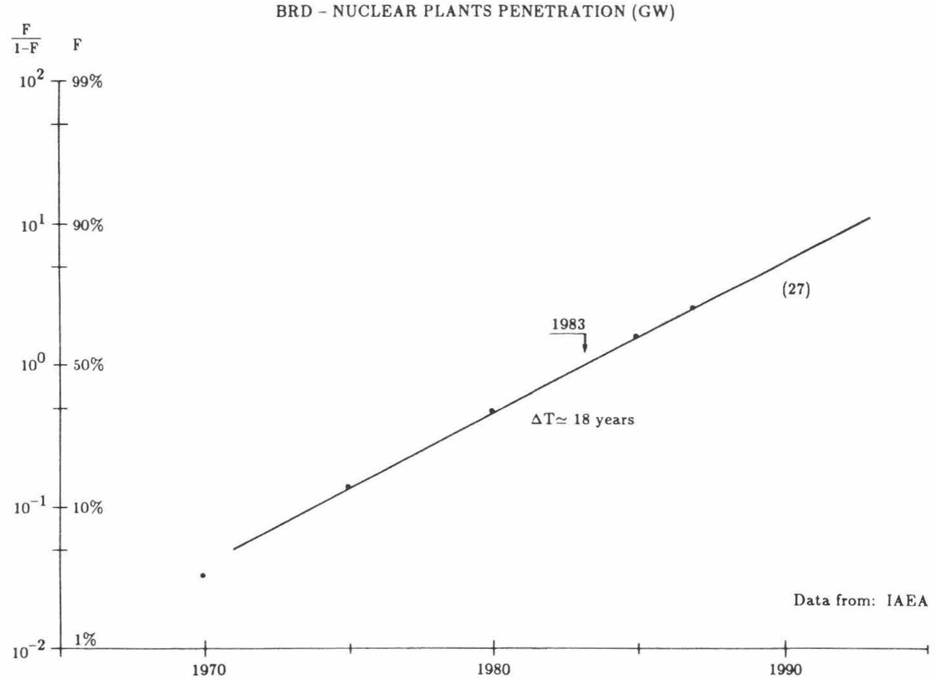

Fig. 9. Here the action is easy to identify and count statistically. The actor is more diffuse. We may assume the electric utilities are the actors. The unexpected and remarkable result of the analysis is the absolute smoothness of the ride in the very rough sea of nuclear opposition for West Germany.

A measurable indicator of public interest for a subject is press coverage. No sane editor can indulge in subjects his readers are not interested to buy. He may certainly somehow stimulate these interests, but this does not change in principle our assumption that press coverage is a mirror of actual interest level in the subsystem of the readers. The cumulative number of articles related to nuclear energy appearing in US periodical literature is reported in Fig. 14. The general character of cultural waves processes does not save the media, and two neat pulses appear for the press, curiously resembling the nuclear completion pulses of Fig. 11. As journalists may be more excited by the rumbling of earth moving machines than by the mumbling of electric generators, we have also analysed the construction starts, measured however in *number* of reactors, i.e. in construction sites. Again two waves.

We leave to the reader the final choice for the causal connection. Our preference is for construction activity being the primary stimulus for the literary activity of the newspeople. In that case, comparing Fig. 15 and Fig. 14 we see that the centerpoints of construction *precede* by 5 years these of media coverage for *both* waves. The time constant of the media is, however, larger (8 years vs 4 years). The situation for dailies and TV coverage is substantially the same, which lends support to the thesis that public interest is primarily to the three prongs of the media.

We have also analysed Spiegel's coverage in Germany, where a single pulse makes things simpler, finding the time constant here is the same for both construction starts and coverage, with a delay of 7 years. Germans brood longer. In these counts reactions to hot events like the TMI accident or Chernobyl accident are kept separate. The articles (or TV coverage) in these cases are neatly represented by pulses of three to four *weeks* (for Germany), probably representing the maximum hold-on attention for a point event. All this ballet is analysed in detail in a report we wrote for the EEC Commission: *On Nuclear Energy and Society*.

The reason why construction of nuclear plants has been stopped, however, is still left open and we will come now to the question. If we look at primary energy consumption in the world or the U.S.A. (including non-commercial energy) we find a neat mean growth of 2.5% over the last 150 years (Fig. 16). A best fit (logistic) done by Stewart in 1980 for the U.S.A. shows oscillations around the trends that are reported in Fig. 17 for primary energy and electricity as percentual deviations.

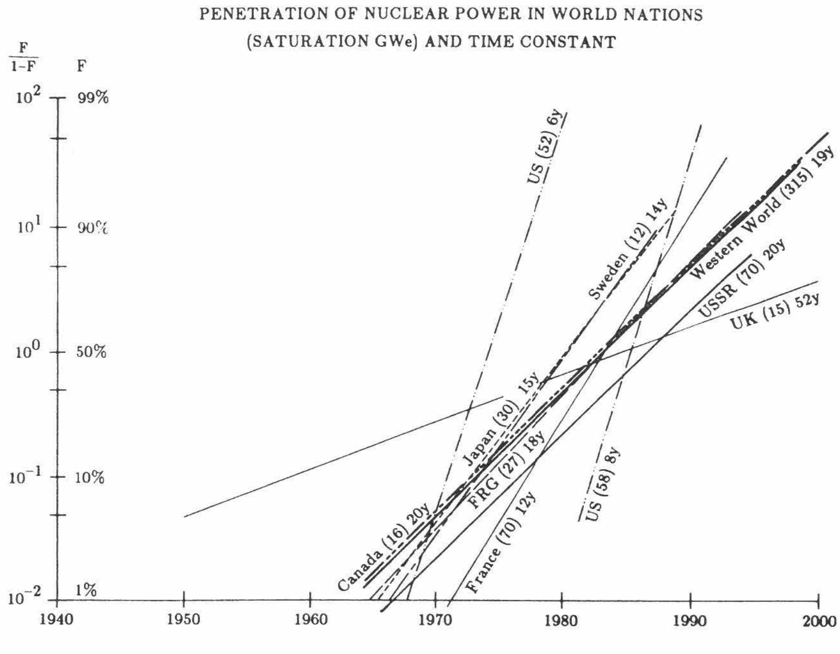

Fig. 10. As in Fig. 9 (and 7). A comparison is made between different countries reporting together their nuclear penetration (GW connected to grid). Data points are omitted for clarity. Saturation levels are in parenthesis followed by time constants in years. All penetration lines move to saturation (>90%) in the nineties.

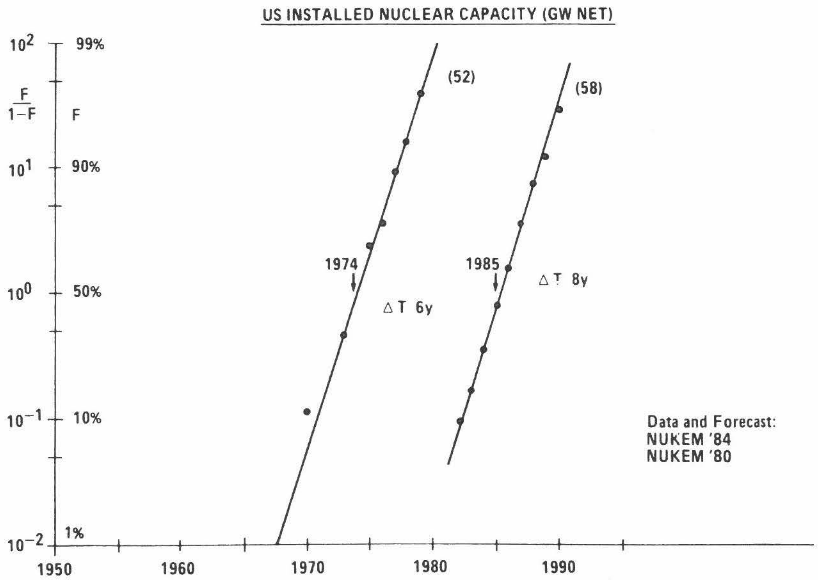

Fig. 11. In the case of the U.S.A. the data are best fitted by two waves of nuclear plant construction. This peculiarity helps disentangle the problem of relating construction and completion of nuclear reactor plants to the intensity of coverage of the subject by the media.

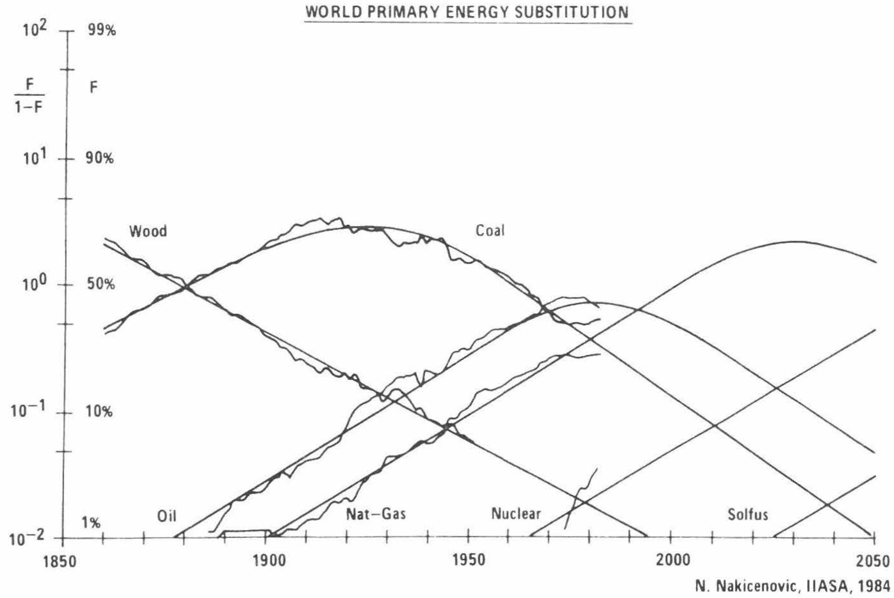

Fig. 12. A grand view of the primary energies substitution at world level can be obtained by plotting their market shares on diffusion charts. All the dynamics of substitution can in fact be reduced to a sequence of diffusion processes. These processes are extraordinarily stable over long periods of time, e.g. a century, which permits robust forecasting, e.g. over 50 years. In this time horizon natural gas and nuclear appear to share our energetic future. New competitors will grow too slowly to leave a dent before 2050. Solfus is solar *or* fusion.

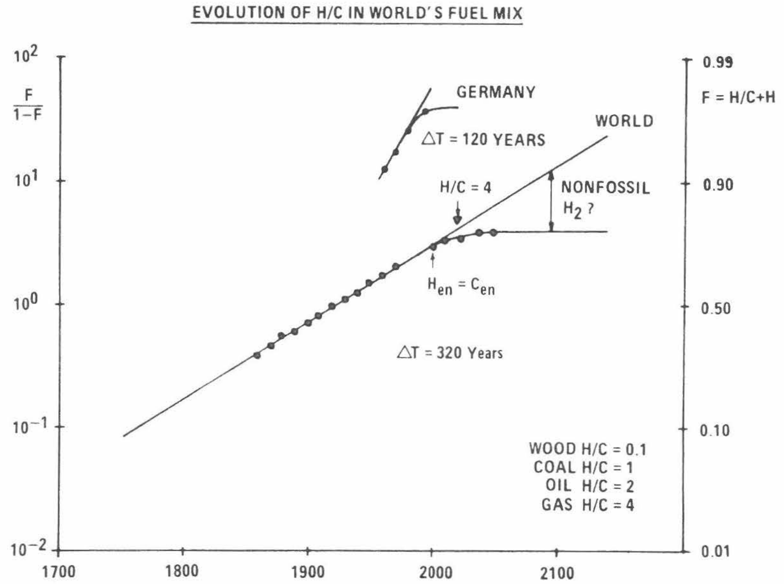

Fig. 13. The shares of Fig. 12 can be used together with a mean specific H/C ratio for various primary energies, to calculate mean H/C ratio for their mix. As the chart shows, the evolution of this mix has the formal characteristic of hydrogen penetrating the energy market to substitute carbon. Assuming the chart unveils a deep feature of the system, the time is now to introduce non-fossil hydrogen (water splitting) into the system, to keep the trend going beyond the H/C = 4 characteristic of methane. Steam reforming of natural gas with nuclear heat can do that.

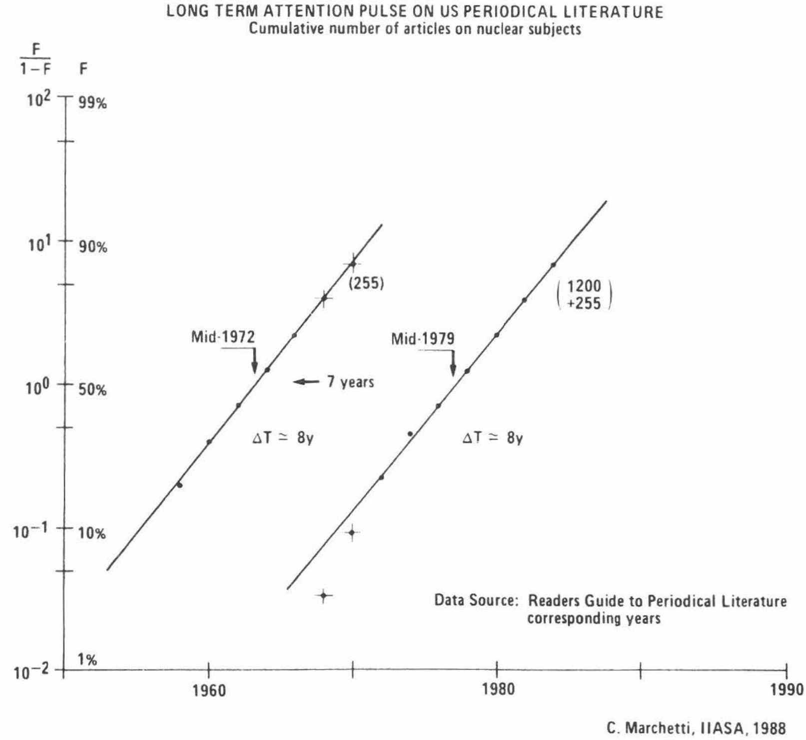

Fig. 14. The coverage of the nuclear subject by the *periodic press* in the U.S.A., like reactor construction, is best fitted by two waves. The second is substantially larger than the first one, with about five times as many articles (1200 vs 255). The centerpoints of the two waves are exactly 5 years apart from the centerpoints of the waves of reactor construction starts (measured in *number* of reactors, not GW). It seems that construction activity stimulates best newsmen. Similar results can be obtained looking at dailies and TV coverage.

Energy consumption integrates over the whole activity of the system and the oscillations reveal a strong pulsation of 55 years length, the Kondratiev cycle. Almost everything in our society is caught in the rhythm, from house construction to criminal activity. Already in Fig. 17 the centerpoints of innovation waves as detected by Mensch and reported in the circles, show their strong locking to the end of the recessive periods, the downward branches of the oscillations.

These ends (the next one is in 1995) appear as walls for diffusive processes, in the sense that everything seems to saturate there, from legislative activity to nuclear power plant construction as we have seen. *Activity will restart with the next wave.* We have hundreds of examples analysed in detail, but we will report here only the case of world steel production (Fig. 18) saturating at around 100 million tons in 1940, starting a new wave after World War II, saturating now at 750 million tons (plus the 100 million tons of the previous wave on top of which it sits). The number of cars circulating in the U.S.A. shows a much similar morphology (Fig. 19).

The conclusion is then that the stopping of nuclear construction has not much to do with opposition of whatever color. As the penetration curves of Fig. 10 show, nuclear energy behaves exactly like any other technology, and the compliance to Kondratiev cycles is part of this orthodox behavior. It is then natural to expect that it will start a new wave after 1995, as steel did after 1940. When we will find a sponsor we will also search for the logic to calculate the saturation level for this new pulse of growth. We have done it for other technologies.

Wrapping up our arguments, opposition to new technology appears to be a well concerted ritual to trim the new dress on the social body. Nuclear energy is here to stay and has to be inserted into all long-term energy plans. Our proposal for a natural gas refinery in West Ukraine (Fig. 20) seems to stand up to the critics, and may well provide the cheapest hydrogen in the largest amounts that the world ever had before. The hydrogen era may well start in this context, with this first large Joint Venture sealing a covenant of peace between East and West.

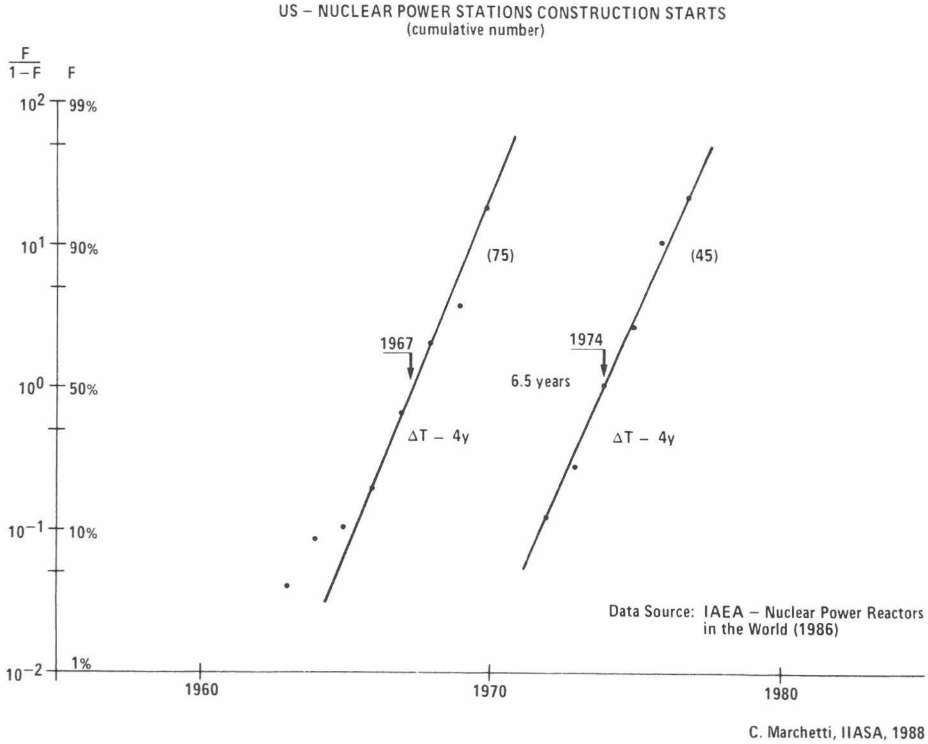

Fig. 15. The construction starts quoted in the legend of Fig. 14 are reported here. The time constant of the two pulses is quite short, 4 years. Time constants of terminations are longer (8 years) showing much spread in construction time, even for the first wave of nuclear reactor.

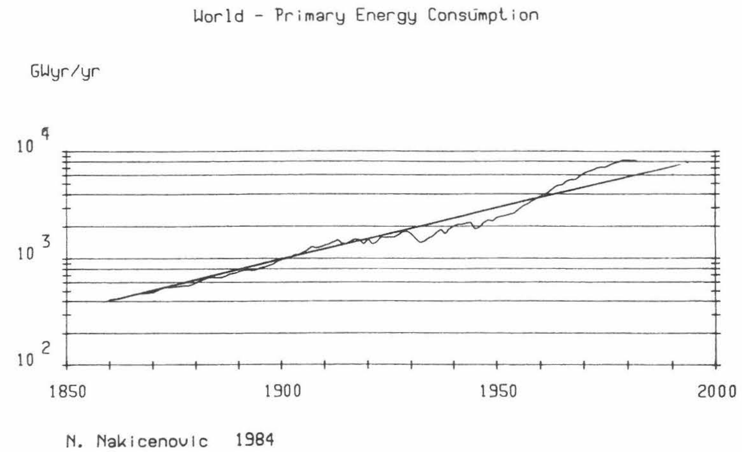

Fig. 16. Primary energy consumption for the U.S.A. and the world in the last 150 years. Non-commercial energy is included. The mean rate of growth is about 2.4% in both cases.

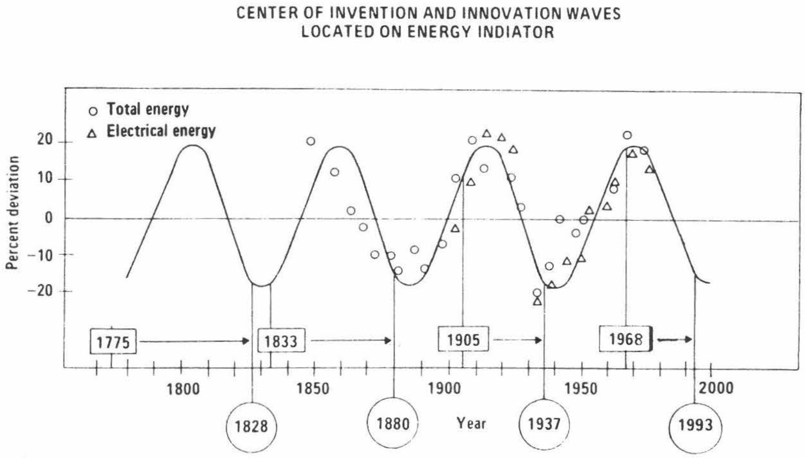

Fig. 17. Best fit (by logistic) of U.S. consumption done by Stewart shows deviations which are here reported as percentages. Both for primary energy and electricity. A 55 years cyclic component is evident. In the circles are reported the centerpoints of innovation waves, and in the squares of invention waves as found by Mensch.

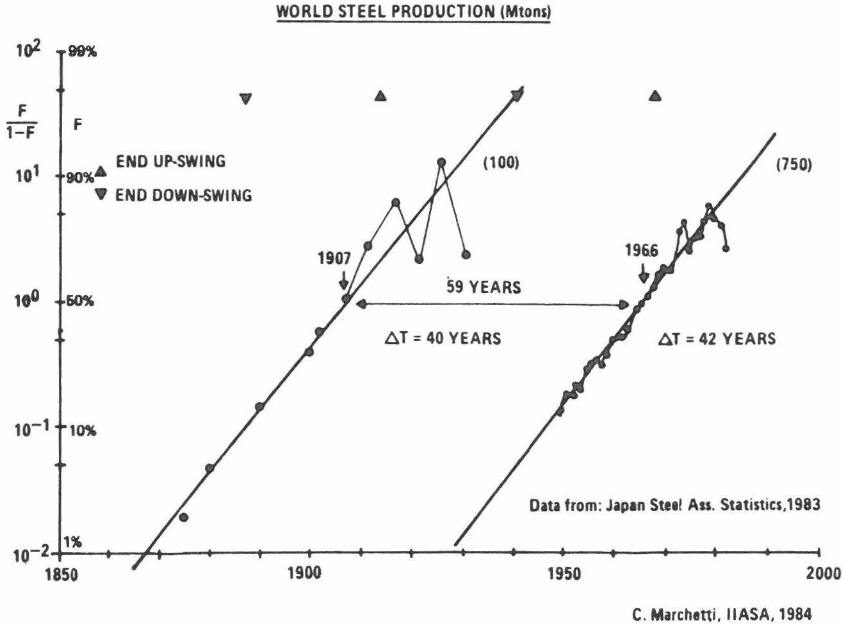

Fig. 18. World steel production during the last 100 years. Two waves are evident saturating toward the bottom of the Kondratiev cycles (1940 and 1995), marked by ▼.

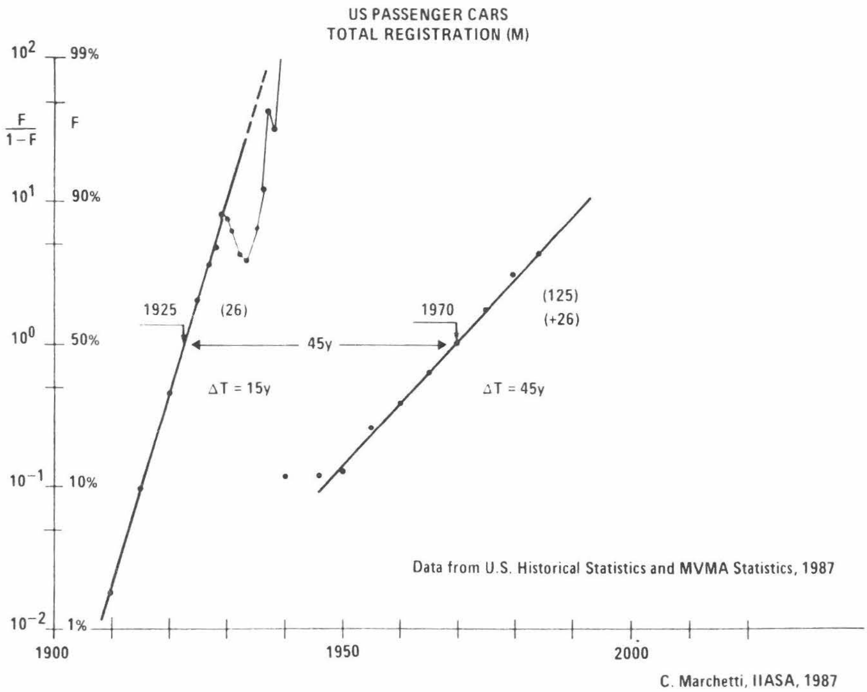

Fig. 19. As for Fig. 18 for car circulation in the U.S.A.

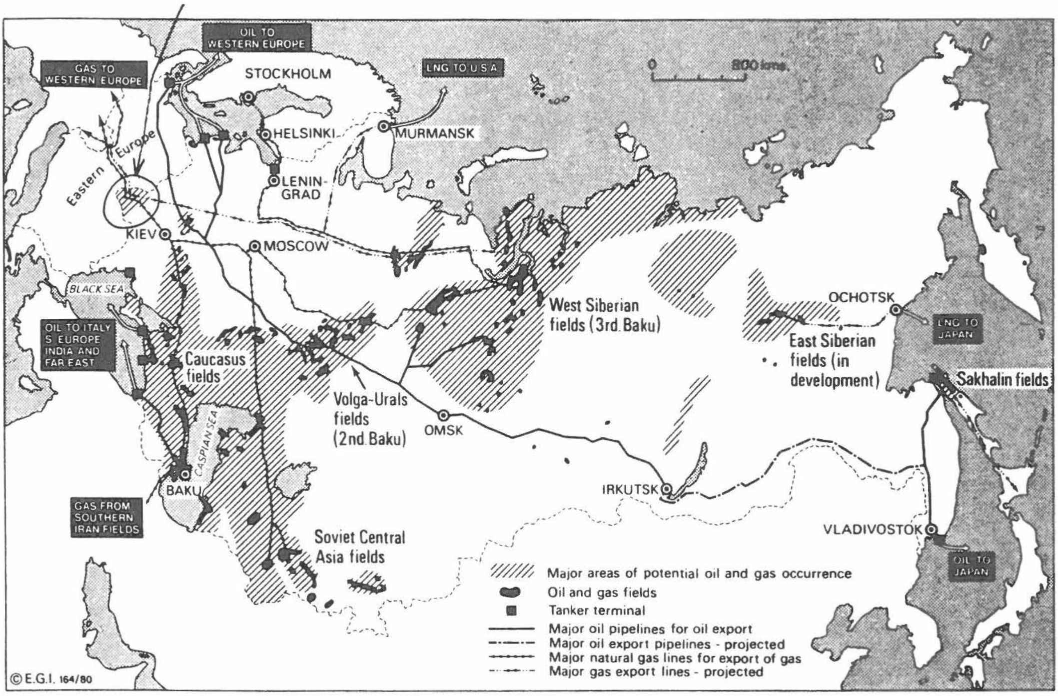

Fig. 20. Map showing the area where the reforming plants could be located and the relevant oil fields. As a CO_2 pipeline will be in any case necessary to retail the CO_2 along the fields, the site of the reforming plant is not critical.

CONCLUSIONS

Steam reforming of natural gas using HTR high temperature nuclear heat can well be the first step into the hydrogen age as it permits *large scale nuclear water splitting with proven technologies.* The fact that the process is open, i.e. requires a flux of CH_4, is not limiting in terms of quantity in view of the large fluxes of natural gas available around the world. It can be limiting from the point of view of the sites if we want to recover the CO_2 for tertiary oil recovery or for final disposal to counter greenhouse effects. The paper attacks the second fact of the problem, that of the large deployment of nuclear reactors on a single site to produce the necessary process heat. It shows that nuclear opposition is part of the Kondratiev long economic cycle and does not modify it. Consequently we should expect a restart in the construction of nuclear power plants during the present decade, on a scale consistent with the requirements of the proposal.

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