

The transition from fossil to solar energy

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Abstract. The wealth of the industrialized Nations is inextricably correlated to great energy consumption. This fact is considered by the leaders controlling the financial fluxes as a detail within the well established economic doctrine of growth, pertinent to a kind of society that should be defended; on the other hand there is an increasing number of observers who consider such trend as a transient, more or less near to collapse. This is a profound discrepancy which will never be solved by scholarly specialized analyses.

This book tries to present a synoptic and necessarily interdisciplinary overview showing the interplay of history and technology, and this implies the language of physics and biology, the texture of the progressing real life. Each subject is touched at the level of an average university education, and the main effort has been to be rigorous and simple at the same time, which of course will appear very easy to understand or difficult, depending on the specific education of the reader. But there is no other way around: either making an effort to learn also what is not familiar, or sinking in the uncertainty of opinionated choices.

Foreword. Each living organism is an open system with molecules coming in and molecules going out, called respectively food and waste. This process is controlled by the individual structure that is maintained. Each living species

feeds itself in a specific way and two different species do not feed exactly in the same way. The counting of the different species is difficult because it is not a sum of units but a catalogue of varieties, therefore the total number

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of species is unknown: the uncertainty can be more than one order of magnitude (a factor of ten or more). The experimental observation says that the total ensemble of the species is self consistent and realizes a quasi stationary dynamical state. This ensemble is called living web or biosphere. We know the power (in watt) of the web with much better accuracy than the number of its elements. It is worth noticing that in thermodynamics the evaluation of an amount of energy (of a gas, for instance) is known with the same accuracy as the number of the constituting molecules because the total is the sum of identical units.

In this scenario the human species is the exception because is characterized by extra activities in addition to nourishment, and this defines the concept of “extra energy” needed for a human society. In this sense the human species is a perturbation within the living web. To my knowledge no one has ever attempted to define the lower and the upper limits of the extra energy necessary for the best performance of a given human society; on the other hand we know that the human societies have invented strategies to obtain the extra energy. For instance:

Animal servant to man,
Man servant to man,
Engine servant to man.

Within the third class the revolution came from the sea: the transition from the sailing ship to the steamboat. Then these machines conquered the land and became ubiquitous thermal

engines, invented about two centuries ago. These are fossil fuel machines and their proliferation has moulded the structure of the industrial societies. On the beginning this was called progress, now is called collapse. Such is the wisdom of the collective human behavior.

What may come next? The scientific discoveries, the understanding of nature does not come by miracle but by labour of slowly advancing steps. It is hard to understand the language of different disciplines and appreciate the immense variety of possible technological opportunities. These opportunities can be ignored, or developed and used for evil purposes, or addressed in the direction of evolution.

The language of the economists and the language of the physicists are external to each other, nevertheless there are facts and problems that involve both of them. Moreover any scholarly discussion about energy perspectives, oil, nuclear, solar, is empty without the consideration of the ultimate actor: the nuclear military power. And that is not a talkative partner. This is a major difficulty in the attempt of giving a synthetic overview on several issues which are specialized and at the same time correlated.

This book is the extension of a set of slides and notes used in seminars and followed by question and reply, and remains structured as a dialogue rather than a didactic text. Accordingly also the references are reduced to the minimum.

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1. Classification of resources. The “exploitation” of natural resources by man differs from the “interaction” with the natural resources by any other living species because man has the possession of artifacts, namely extensions of his interactions with the outside. Artifact means something that is superimposed to the continuous changes that characterize the natural evolution of the biosphere. Man is the exception. The human species artifacts appear with two main aspects: one that operates in the collective interactions within the species, or man to man, and the principal actor is money; another is the ensemble of the mechanical prosthesis, or machines that man creates and controls. These machines operate both within the species and outside. Also money operates on the ambient but indirectly, namely interfaced by the operation of the machines. This distinction is important. Vegetables and animals control their own interactions in a fixed and specific way: that way which is proper to the given species. Man controls himself plus the machines; this is a great difference. In fact we may say that the global evolution of a planet with man and a planet which was an identical copy until the human species appeared, at present time are different. We have no actual realization of this twin situation, and this is

the reason why the recent studies on the climate changes operated by men are so difficult. Let us start with the fact that both the operation of money and the mechanical extensions have effects on the social life and also on the ambient. The mechanical extensions require power for their operation and that power came first in history as natural power: man power, animal power. Later, at the end of the eighteenth century, there was the new entry of the combustion engine. The circulation of money in its turn is powered, or sustained, by the incessant human existence, which manifests itself with actions, both active and passive: desire (active) and need (passive); offer (active) and scarcity (passive) that accompany each individual from birth to death.

After this introduction on the concept of “exploitation”, let us discuss the physical definition of natural resources. There are two main categories: fossil and renewable. First remark: the word renewable is ambiguous. The correct distinction is: fossil and flow. The flow is the solar flow that is measured in watt, is power. The fossil is measured in joule, is energy. The solar radiation, stellar radiation in general, is the only continuous power flow existing in the stellar cosmological era. Stars emit energy, a quasi-constant amount of energy per unit time. This emission is a fundamental event of nature. In fact, what is not steady emission is transient: transient is the birth of the star, transient is the death of the star. A planet has in general a faint endogenous dynamics (compared to a star) and a

surface dynamics, which is powered by the flow impinging on it and originated by a nearby star. For constant radiation flow received, there are two channels of forced dynamical manifestations:

- a) fluid surface dynamics and its kinetic energy circulation,
- b) operation of the metabolism of the biosphere (if such biosphere exists).

For a star similar to the Sun, the time interval of regular radiation emission is very long (10^{10} y, or ten billion years): this interval is “forever” on the human history timescale.

The concept of biosphere is old and rather complex. Its modern version is an entire body of ongoing research [1]. Suffices to say at this point that the biosphere is powered by the solar radiation.

We have seen that the solar flow goes into kinetic energy circulation and into metabolism of the biosphere. Which is the ratio between the two ways? Science is able to evaluate approximately such ratio, is about 10^2 (one hundred) [2], but is not yet able to explain why it is such (and not for instance twice or one-half). We may assert reasonably that if the eccentricity of the terrestrial orbit were higher (how much higher?) the power of the biosphere would be less, if the eccentricity were still higher no biosphere would be possible. This orbit dependence is only one among the many new fascinating problems of eco-physics [3, 4, 5].

The contrary of the regular flow is the fossil, namely something that includes the concept of “past”; fossil in-

deed is something that has been accumulated by past events. Among the past events, there is the transient of accretion of the planet Earth: in this way the inorganic composition of the Earth has been accomplished. At the present time all elements of the Mendeleyev table can be found on Earth [6]. Their location and percent abundance changes obviously from place to place, because these details are consequences of the cosmological accretion itself plus tectonic events that, after the accretion, helped separating or mixing the various parts of the Earth. These events in the timescale of mankind can be considered as terminated (not rigorously true, see earthquakes, volcanoes...) and therefore constituting a constant datum. This is the definition of fossil resource.

What can be defined as being a resource or not being a resource depends of course on the development of science: for instance before the discovery of nuclear physics there was not even mention of either fission or fusion processes nor of the heat released by natural radioactivity. We know today that all this exists, and moreover that some of this can be manipulated. Looking backwards, for instance, fire was known since a very long time but thermal engines came after sophisticated concepts of thermodynamics became part of the scientific domain. Transport of energy by electric conduction and relative networks of transport came even later. The access to the kinetic energy of fluid motions has changed in time, following the course of history of var-

ious populations and their typical technological acquisitions. Direct access to the solar radiation (photo-voltaic) implies knowledge of quantum physics and therefore is still more unevenly possessed by different nations.

Let us consider now the biosphere. All planets are made of matter and are not so different from each other in atomic composition, but a few, or perhaps only the Earth, houses the biosphere. It is disturbing the thought that the Earth is alone with respect to life, and in fact research for extraterrestrial life within and outside the solar system is going on. But this is new: at the time of Giordano Bruno the hypothesis of extraterrestrial life was heresy. The terrestrial biosphere has evolved with typical timescales that are different from the inorganic timescales of the planetary non-equilibrium thermodynamics. What happens inside a planet manifests itself in the endogenous energy flow measurable at the surface. These problems are object of

paleontology and geodynamics. For what concerns us here we notice that within the evolution of the biosphere there have been also “past events” which have produced fossils, the biological fossils, or organic fossil resources, mainly coal and hydrocarbons. In conclusion we may consider the following table describing inorganic and organic; flow and fossil.

Within the general definition of Table 1.1 is important to recall some further details relative to the comparison between molecular (Table 1.2) and nuclear resources (Table 1.3).

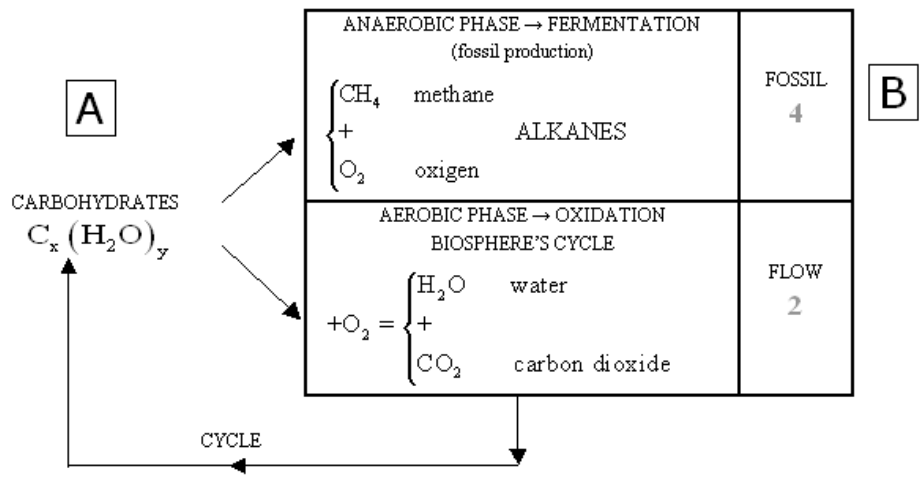
Carbohydrates are the main constituents of the living biomass. Following the biosphere’s cycle, flow 2, they become H_2O and CO_2 , and by virtue of photosynthesis produce A again.

If instead the anaerobic phase occurs (mostly during the transient of the carboniferous), the fossil alkanes are created and buried under ground, the event B. The fossil B is interesting only for the human species. The present behaviour of the

Table 1.1

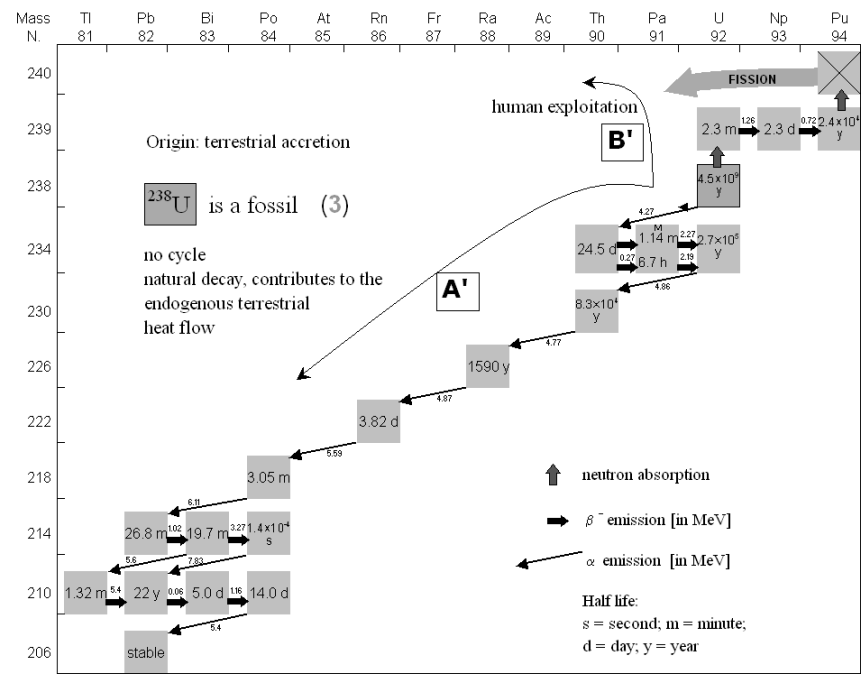
	INORGANIC SPHERE	BIOSPHERE
FLOW	Direct: solar flux, photons Indirect: motion in hydrosphere and atmosphere	Plants and animals providing food: Macromolecules belonging to the cycles of photosynthesis
	1	2
FOSSIL	Metals, mineral compounds usable for: a) standing structures b) sources of energy, mainly nuclear energy	Carbon and hydrocarbons mainly originated in the carboniferous era.
	3	4

Table 1.2



See details of **A** on Appendix I.
See details of **B** on Appendix II.

Table 1.3



economy is an extremely short transient (a few decades) totally dependent on the fossil [B].

The nuclear fossil does not perform a cycle. The ^{238}U nuclei arrive to the planet Earth with the process of accretion: they are a cosmological legacy. More precisely heavy nuclei are created in a supernova explosion: the formation of the Earth follows such kind of event.

Due to natural decay, uranium, together with other nuclei, contribute to the endogenous heat content of the Earth. Typical timescale 10^9 y. This is the natural path [A], completely different from [A].

But the fossil uranium can also be used by the man made technology: is the path [B] that has a twofold outcome, reactors and bombs [7, 8].

[B'] is analogous to [B]. Notice however that the fossil [B] burns completely with the atmospheric oxygen which is present in excess by virtue of the preexisting cycle [A]. The fossil [B'] burns instead by virtue the critical mass within the reactor, therefore never burns completely. Reprocessing of the residual fuel is necessary; alternatively the residual fuel can be abandoned.

See comments on [B'] restricted to the civil use of nuclear energy on Appendix III and IV. On Appendix V, there is a remark about nuclear reactor safety.

2. Access to resources. A glance at Table 1.1 introduces the following concept. The resources should be considered not as abstract fixed definitions, but rather as ever changing

inputs on the human history. This way of thinking is imposed by three facts:

- The understanding of the physical and biophysical phenomena depends on the continuous acquisitions of our scientific knowledge.
- The access to the resources, that are very irregularly positioned on the planet Earth, depends on the technology.
- Possession follows from technology; but technology, unlike science, that is universal, is occasional.

For instance, a resource may belong to a nation that does not have the right technology for its extraction and use, while that technology is present in another nation not equipped with the above resource. Knowledge, accessibility, actual possession, do not constitute a homogeneous mix but exist in the heterogeneous, unbalanced, reality. This is why certain discussions are so difficult. The estimates of oil reserves, uranium reserves, wind availability, photovoltaic availability, bio fuel availability etc are the outcome of serious inquiries which, by the way, are in part classified information. The prediction of resource durability needs the formulation of “economic scenarios”, which constitute the least credible art of forecasting. Many good men amply supplied with information, and greatly endowed with authority, fell because of wrong forecasting (from kings to top managers). The real issue is how technology is manipulated and how is developed, the two things coming in strict conjunction. The energy resources are conjugated to the

technologies of extraction and use; from this obvious remark follows that the number “energy still existing” is not the only parameter of the problem but rather one among many. We should rather try to understand how different societies develop and decay in relationship to the technologies that they nurture, and interact with, in ways that are at the same time beneficial and detrimental. The perception of civilization is spelled in different cultural frames that not always talk to each other. The languages of economy, of religion, of physics are disjoint. From time to time, the disjunctions come together again as collisions. Having ignored each other was not so good. For instance, the average consumer (even cultured consumer) only in recent time has acquired perception of the famous logistic curves describing the time dependence of the fossil energy consumption. In reality these curves are part of studies financed by the oil companies several decades ago, both before and after the Second World War. These information have been ignored for two reasons: the consumers are passive, the entrepreneurs act on the short time scale. But, no knowledge, no remedies [9, 10].

The access to resources like oil and uranium is complex and very expensive; it requires the existence of a tough structure, a purposeful assembly including engineers, workers, huge machineries all kept together by money. Such enterprises do not appear in the day-by-day worries of the human beings, are not part of the spiritual values that motivate ideals

and expectancies. To fix the ideas consider this meditation. The cost of the Manhattan Project (the first two nuclear bombs) [11] was of such a magnitude that only the USA had the means to risk the financial bet of such enterprise, the Nazi Germany was far away from such capability, although the scientific endowments of the two countries were perfectly comparable. Was this situation predictable? Yes, but very few people grasped that. The nuclear bomb came for the human society as an external miracle. Well, it is not a miracle. We should rather think of this: Who are the men that have control of these arms? How they arrived at the position of control? Which is their culture, what do they know, what they have in mind?

3. New land, larger boundary. The logic framework presented in the preceding sections is an acquisition of the last half century. Before this time the perception of the relationship between wealth, privilege, social power, well being and natural resources was different, and changed in the course of history. Why paying attention to history? The reason is that the social structures, those complex combinations of economic and ethic interactions, determine the slowly changing national identifications and the international interactions. Now, these identifications and interactions do not incorporate easily the inputs of science and technology. For instance, the way of teaching economy is very often founded on axioms stating that the dynamics of the circulation of

money obeys its own laws, the physical constraints being relegated to the place of faint or distant boundary conditions. Similarly the religious structures attribute to themselves absolute roots whereby again the physical inputs related to the ever progressing scientific knowledge are resisted. This causes that the rendezvous with physical reality come again and again as collisions. These are not at all irrelevant remarks; all this is part of the historical legacy. Unfortunately, learning from history is difficult. At present, the technological man has tools that cover the entire planet: air transportation, satellite surveillance, monetary transactions performed with electronic networks, etc operate in a matter of minutes or hours and from this global dynamics comes the concept of technosphere. Nevertheless, the historical cultural legacy is still rooted in different concepts.

From the invention of the wheel, of the roads travelled by horse-powered carriages, the sail and the maritime fleets, knowledge and territorial conquest have been closely related: no equilibrium on a sphere but infinite linear expansion. Past empires where accounted by the control of geographical domains with boundaries expanding by steps that were considered benchmarks of power, well being, prestige, larger monetary fluxes, manifestations of superiority of art, and law, and beauty. Recall Alexander the Great and his short lived, travel-like military empire, the long-lived Roman Empire that started to decline when the extension of the boundaries

became structurally detrimental rather than beneficial, such that non-defence of the boundaries became by definition collapse [12]. The Carlo V Empire was powered by the resources coming from topologically disconnected territories, the colonies. While the instruments change, what remains dominant anyhow is the expansion: enlargement of the wealth, new goods, new terrain, new taxes, new churches, new fortresses, etc. Today the American empire has incorporated the above concept of extension of territory as extension of knowledge and value. Spacecrafts landing to distant planets are expected to conquer new mines, new biospheres, and that is accomplished by wars against alien creatures who are nothing else than the cosmic incarnation of the barbarians, the morally inferior populations, or the new brand of self-reproducing anti-democratic terrorists.

The distinction between mining economy and flux economy is resisted: new resources must exist, will be found; steady state economy is a despicable concept. Nevertheless, at the transition from mine resource to flow resource the relationship between growth and knowledge necessarily must change.

For physicists the concepts of reversible and irreversible, forced and conservative, open and closed, stationary and transient are acquisitions considered deep and fertile. It is inside this scientific ambient that the concept of biosphere is taking consistency. The understanding of the biosphere is not disconnected from the

understanding of astrophysics, these are frontiers of the mind, and are unlimited.

It is to be hoped that economists and politicians may also acquire in the future the formal instruments necessary for the understanding of the problems that are lying beyond the recipe of perennial growth.

4. From underground mine to surface flow. The Second World War was a war among engines equipped with men rather than men equipped with rifles. Engines needed kerosene and coal, which is different from the fuel of the ancient soldiers that was uniquely athletic strength, prowess, endurance, stamina, acceptance of death in fair proportion between given and received. Therefore, in a war of engines the winner was not the country with superior engines but the country with larger energy supply to feed them.

In general, in time of peace, given equal engines, great power means great control of resources. Resources move the commercial trade and attached to it the economic well-being and the related privileges all circumscribed by military protection. This was the logic underlying the cold war. Not so paradoxical that while men belonging to either side were eager to exchange theorems if scientists, imagination if artists, all kinds of curiosity if intelligent human beings, a small group was busy inventing hostile ideologies necessary to justify the competition for resources. What happens if the mining resources become less abundant? The mining way of life

must change and give place to the flow way of life. We may expect a bifurcation: science is perfectly mature for the inversion of trend from misuse of energy to intelligent use; on the other side the economic structures articulated on mining according to the present formulations are incompatible with the inversion of trend.

5. The interaction of bank and resource. *The Second World War separates the era of the old European hegemony and the new American empire. Old means before the nuclear energy and new after the nuclear energy.*

Money circulates in a web of manifold interchanges among specialized human activities. A single specialized activity is not self-sustaining; the combination of few activities is not self-sustaining; a carpenter and a farmer either considered alone or in interaction are not self-sustaining, etc. A large number of human specialized activities are necessary to keep a society, considered as a complex market, ongoing. How many? Nobody knows.

A fascinating problem of topology is to find the complexity of a network that maximizes the global circulation, namely the general wealth. No matter how wealthy is the circulation once money has been assigned to each $\{ij\}$ couple of interactions we must face the fact that the physical $\{ij\}$ interchange happening among living individuals is irreversible; on the contrary the $\{ij\}$ money counterpart is not irreversible: is an abstract number (in ancient times written on a coin) which has several properties typical of game theory like repeatability, finiteness,

discreteness of rules, applicability in different places and with advanced or retarded times, etc. Such abstract numbers nevertheless cannot evaporate or be created at random: in conclusion a banker must exist, and must be a human banker, not a symbol, or a mere rule of self-consistency of the monetary web.

The existence of the money web is sustained first of all by the life of the human beings, which is granted by the natural reproduction process. Past pandemics with reduction of the population resulted in poverty; similarly, the recommendation for proliferation is frequently used particularly in poor countries. In addition to this, the conquest of territory mentioned above injects extra action into the existence of society. So bank, web and resources operate as a unity. Certain events in history have put at risk the existence of the banker and strong reaction followed. Other events put at risk the complexity of the web, and asphyxiation ensued. Other events, errors, natural phenomena, have put at risk the natural resources and again troubles appeared.

The most magnificent monuments of past civilizations recall two important authorities: banker and emperor. The emperor guarantees the web (law and order for the people), the banker guarantees that the abstract money is real and is there.

Let us talk about the banker. An excellent short lesson about banker, emperor, resources is found in the book *La banque en occident*¹, sous la direction de H. Van der Wee, Albin Michel 1992 [13].

From 1935 to 1940 Germany was rich or poor, was powerful or weak? The description of those events seen with the eyes of the banker is revealing and quite convincing.

[...] La politique d'émission et d'endettement sans frein dans laquelle s'engageait le pouvoir nazi provoqua au début de 1939 les protestations de la Reichsbank, présidée par Schacht, l'artisan du redressement économique de l'Allemagne. Balayant les propositions de financer les dépenses par la fiscalité rendant à la Reichsbank le contrôle des marchés monétaire et financier, Hitler congédia Schacht et ses collègues du Conseil de direction de la Reichsbank.

L'épuration du conseil de la banque fut suivie de la promulgation le 15 juin 1939 d'une nouvelle loi sur la Reichsbank. Tout en stipulant une augmentation des prescriptions de couverture et une limitation de la reprise des bons du Trésor, la loi obligeait la banque centrale à faire crédit à l'Etat sur ordre du Führer et Chancelier du Reich. [...] [Page 354]

The western bankers could not stand the event that large amounts of money would reside or, better, would be controlled by Hitler, a non-banker. This would put at risk the existing monetary system. Consequently, the bankers inverted their course in 1939: from the financing of Germany, potential carrier of trade in the eastern areas, to the opposite direction, business with the enemies of Germany. Presumably, they felt anxiety, the war involved uncertainties but a banker cannot vacillate, he is not man for passions, he is forever. Soon after the war, Stalin, the unexpected winner,

took control of the soviet block financial dynamics. Again a non-banker playing the banker. Stalin was no longer a political leader permeable to the western monetary structure but the sovereign of the rouble, the alien currency. This again was not tolerated. There is logic in all this. Money is important and its existence must be protected against uncertain adventures.

The next point to discuss is this: the kind of market based on the unbounded access to fossil resources was a friend of money at the onset of the bonanza, but its stability is again at risk. We need to discuss the concept of health of the money web.

6. Fossil economy and its asphyxiation. After World War II the American empire was stronger than any other empire of the past, due to the leadership in nuclear weapons, and to the capacity of control of the fossil resources in large areas of the planet. The scheme of the consumer's economy is shown in Figures 6.1 to 6.5.

P indicates producer; with this word we mean also what production implies: structure and purpose, namely the apparatus that is able to perform heavy projects. The maximum among them was the Manhattan Project. Then we must consider oil drilling stations, refineries, fuel distribution, dams, spaceships, space stations that are examples of heavy projects. Manufacture is embodied inside the circle P. It can be heavy, like the military and civil engineering, or light as in the case of Coca Cola production, show and entertainment etc.

What happens to the web of money circulation? The scheme shown in Figures 6.1 to 6.5 is of the type one to many. Many are the consumers. In the figures the web of the consumers is indicated with a line to emphasize that is a sort of web with little complexity. How can the consumers be able to pay for the products if they do not participate to a network of interactions able to sustain the circulation of money? Decreasing complexity of the web is synonym of asphyxiation, death of the economy. A web of the type indicated in the figures presumably may exist only under two conditions:

- The consumer's web at the beginning was not so simple, and today there are still hidden complexities that support the production of money among the consumers, and consequently the vitality of the total web. But the complexity is eroded; in other words the scheme is a transient.
- The extraction from the reservoirs is increasing, the cost of extraction is zero, the cost of disposal is also zero, money is injected into the consumer's community from the bank. Such system is ill, but does not show the illness until growth goes on. Again is a transient.

In both cases collapse is the asymptotic outcome.

The symptoms of collapse are visible in the fact that the consumer's web indeed loses multiplicity.

The consumers are decreasingly articulated or in other words less able to do something creative with money; they have neither capacity nor outlets.

The money accumulated in the bank during the process many to one must be channelled somewhere and the somewhere is grand works: bridges, tunnels, skyscrapers, etc. Works that involve small groups of specialized operators, not the large community as a whole. The community is relegated to the role of passive spectator.

The citizen with needs satisfied at the Mall has no longer reciprocal offers and consequently active choices. The citizen with sexual desires formulated for him by TV no longer knows the complexity of the person to person interactions and consequent reciprocities existing within a multiform web. The above schematic remark refers to the problem of web conservation and should be compared to the remark of the preceding section that was about money conservation.

These last two sections show the origin of the decline of the fossil dependent society. The concept of web appears in modern non-linear mathematics and ecosystem theory [16]. The concept of GNP (PIL) comes from linear calculations therefore cannot be a good indicator of the complexity of the economic dynamics or, conversely is applicable only to the rudimental economy of the kind one \leftrightarrow many.

An interesting analysis of the complexity of a particular society-web is found in Goethe, *Italienische Reise* [14], second visit to Napoli, days 28-29 May 1787. Ten powerful pages are dedicated to the description of the daily manifold activities of the *lazzari*², not at all marginal beggars but

busy creatures of all ages, children and adults, actors in a self-supporting dynamics. Goethe is not an economist, his view is deep, he talks of men, not numbers. Pay attention to these facts.

The country around Napoli was still uncontaminated and fertile both in wild and cultivated areas. See the discussion of the natural products incoming to town and the natural wastes outgoing.

The monarchic system is imported rather than endogenous, and the resulting society is tending to political disengagement rather than engagement. This is a millenary property of south Italy and in general of the fertile and desirable areas of the planet. The French revolution is only two years ahead; its reverberations arrive to Napoli much later, with the revolution of 1799.

Goethe is rather alien to political issues; he compares the different conditions of the physical ambient pertinent to north Europe (his own country) and south Italy. This link between man and nature is appreciated in a subtle way. He has a profound insight on the relationship between poverty and wealth, degradation and happiness that is not reduced to money or no money, have or have not, namely the simplification that characterizes the numerology of the economists.

In the night of May 28 Goethe walks along the pier of the harbour: the stars, the waves in the sea nearby, peace. Think of a walk like that in a night of the year 2006, among the human and physical debris of the post-industrial Napoli.

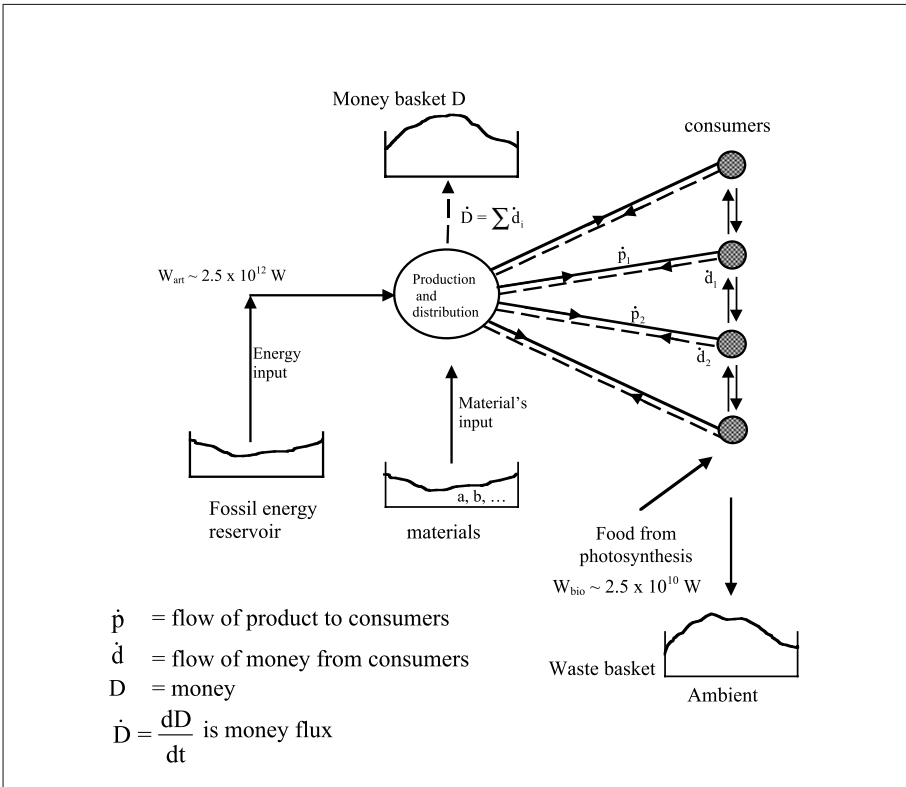


Figure 6.1 Domestic owner of oil.

Look at the numbers in Figure 6.1. The average man needs a power $\pi_{nature} \sim 100 \text{ W}$, number that comes summing basic metabolism $\sim 80 \text{ W}$ plus various articulated activities. The wealth producing machine has $\text{GNP} / \text{year} = \alpha \text{ energy} / \text{year}$, where α is a conversion constant. For the USA $\text{energy} / \text{year} \sim 2.5 \times 10^{12} \text{ W}$. This means *per person* $\pi_{artificial} \sim 100 \times \pi_{nature}$.

The ratio $\eta = \pi_{nature} / \pi_{artificial} = 10^{-2}$ can be taken as a measure of the inefficiency of the GNP producing machine

in the consumer's structure shown in Figure 6.1 and the following.

This is a particular case of scheme 6.1, in which the product p_1 is simply energy for direct consumption.

The foreign owner can be paid, as shown here, or subjugated. In the second case there is no basket D_2 .

Different Nations protect their own markets with appropriate international regulations.

Doing business together, or fighting. This is the ideal asymptotic limit.

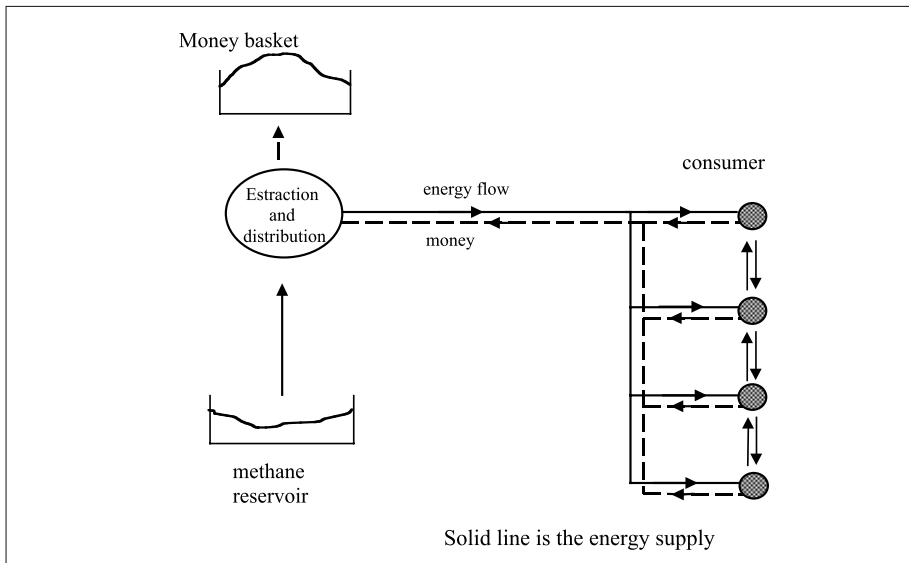


Figure 6.1 Pipeline.

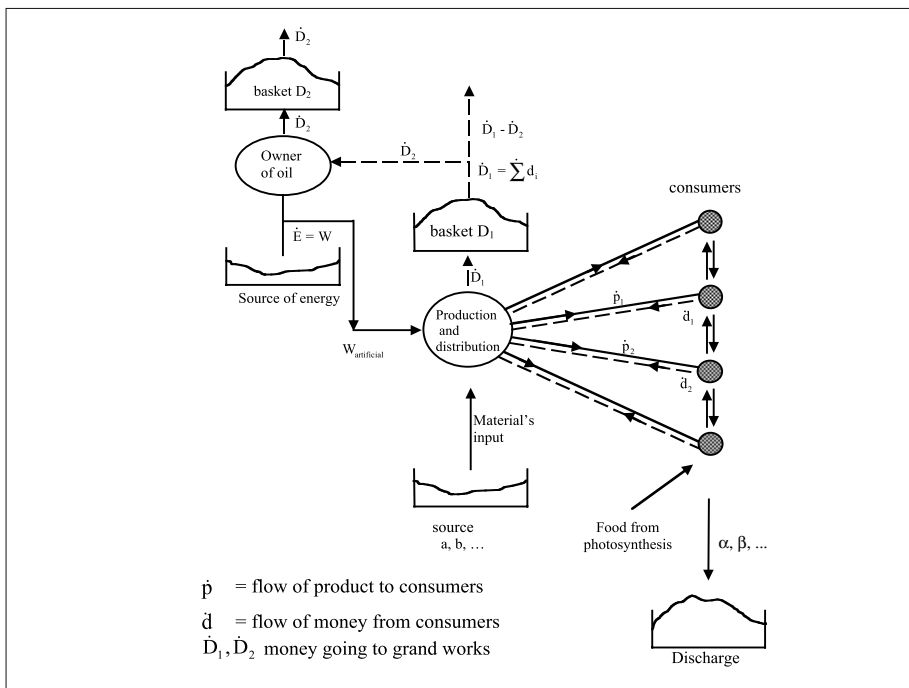


Figure 6.2 Foreign owner of oil.

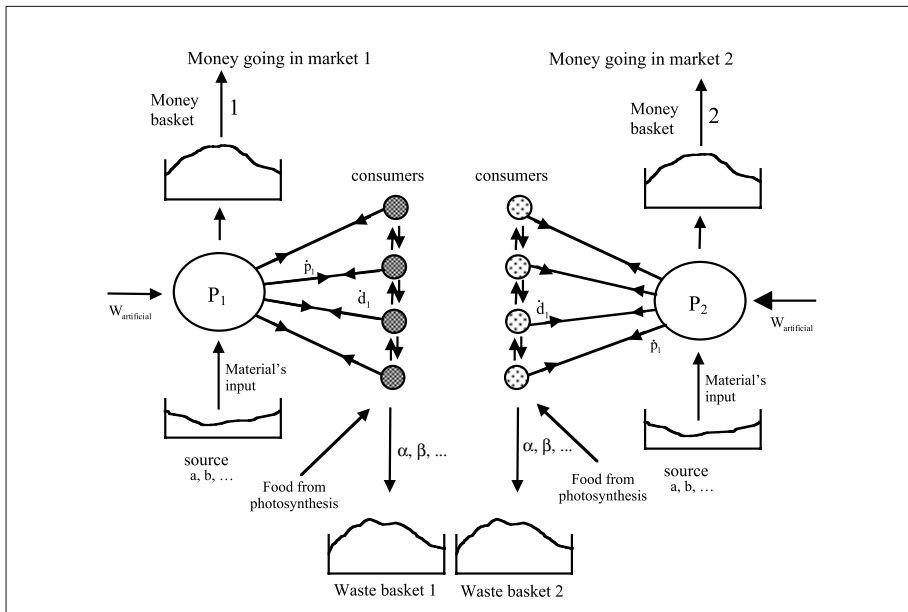


Figure 6.3 Disjoint markets.

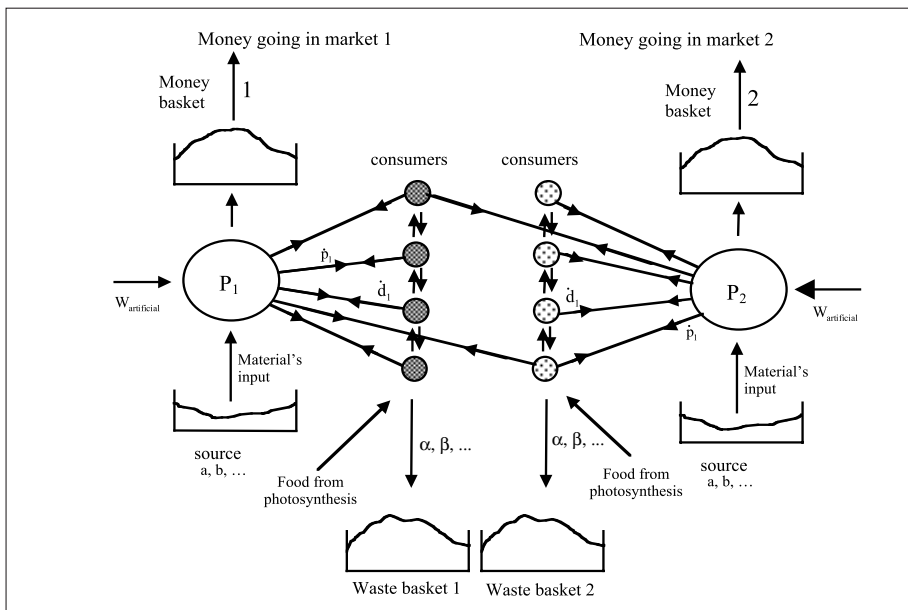


Figure 6.4 This graph is identical to that in Figure 6.3 except that the two producers begin to steal consumers to each other.

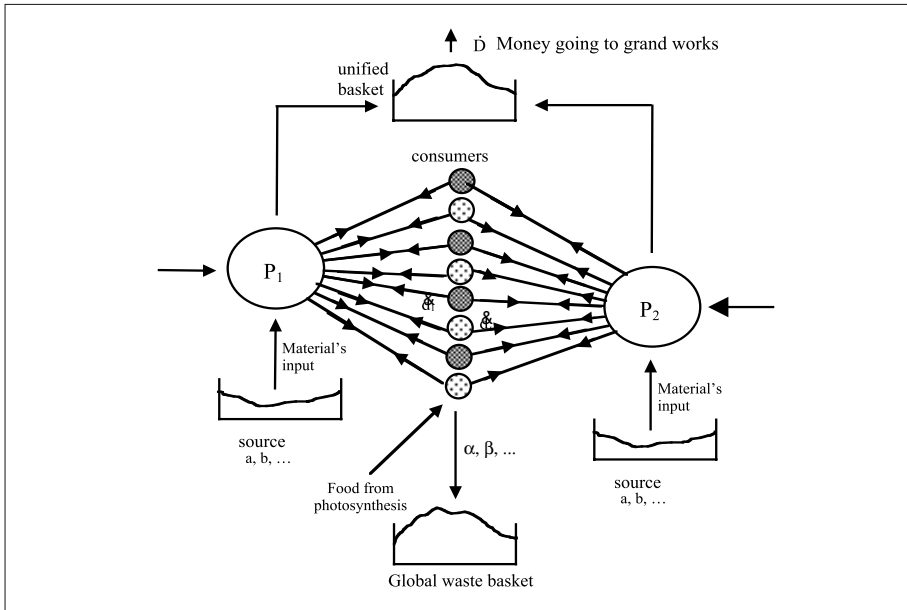


Figure 6.5 Global market.

7. The web of money in the energy flow system. In chapter 5, I have talked about the reality of the money. But this reality does not exist if the web of circulation is not preserved. In chapter 6, I have talked about the reality of the web. But this reality does not exist if the complexity of the web itself is not preserved. In this section the discussion is about complexity in general.

The schemes shown in chapter 6 are not self-sustaining and the collapse comes from two directions:

1. The flow extracted from a fixed fossil reservoir begins to decrease.
2. Even if longer lasting resources were utilized (the ^{238}U breeder reactors) and the decrease was postponed the web of the consumers would die of internal asphyxia.

Presumably the disease 2 “internal cause”, comes first, its symptoms are indeed visible. External causes instead belong to events like ambient changes originated by the release of chemical compounds which perturb the natural cycles.

Notice that members of the privileged elite are already on the road of fossil fuel independence. New houses can be and are built according to the knowledge of passive solar architecture. The eventual backup in cold climates is easily obtained by wood burning. This requires a small amount of wood produced within the garden of the wealthy. It is the population of consumers that remains dependent on fossil fuel. On the side of the elite the solar energy life already exists or is easy to obtain. It is the

scheme of the web described in chapter 6 that cannot survive.

Nevertheless, the creation of a different order is resisted because a) the members of P wish to procrastinate their bonanza, b) the members of C are unable to take care of themselves. The complex web has been destroyed by the fossil way of life since many years.

It is evident that by repeating the “one \leftrightarrow many” scheme is not possible to cover a spherical surface. A sphere cannot be covered by such subunits because the wastes touch the resources; the producer becomes consumer of himself.

Consider instead the two examples of Figure 7.1 made of rings that cover a sphere. The separation in producers, actors, and consumers, spectators, is no longer present in Figure 7.1. The members of the units (rings) are both actors and spectators; in other words a sort of law of reciprocity must act. This is what the illuminist Goethe understood and what the retrograde nuclear empire has forgotten [17].

8. Man as a member of the biosphere. The only perennial flow of incoming energy is constituted by the solar photons. Correspondingly, the only perennial flow of waste is the flow of outgoing terrestrial photons. This implies that matter must circulate and only radiation must appear as incoming and outgoing flux. This is shown in Figure 8.1.

Explanation of Figure 8.1, the trophic chain.

From left to right. In L there are photochemical reactions with energetic photons coming from the Sun and not thermalized yet. Oxygen is produced and released to the ambient at temperature T , and a complex molecule EA is hydrogenated and transferred to the Calvin cycle in D (dark) at temperature T . In the Calvin cycle hydrogen and CO_2 are the inputs, glucose is the output. Glucose is the biological fuel. The Krebs cycle is the combustion engine where oxygen and glucose are the inputs, and the output is H_2O and CO_2 plus work. Work is used both within the organ-

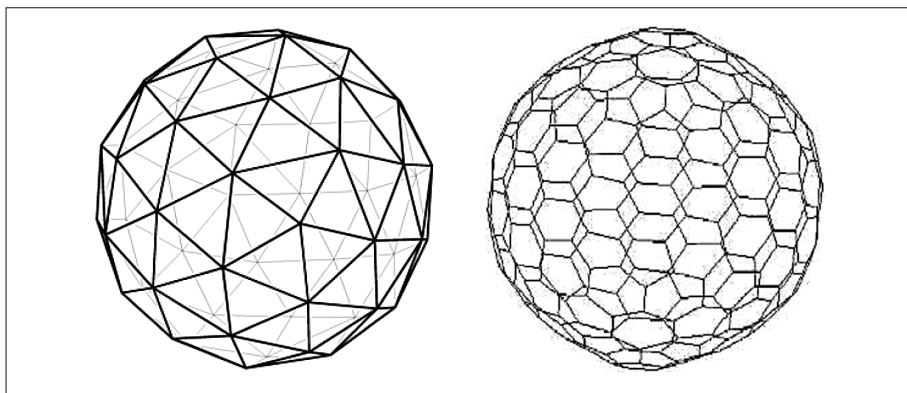


Figure 7.1 Web covering a spherical surface.

ism itself, internal work, and in the actions that the organism exerts on the outside, external work.

Finally each dead organism returns H_2O and CO_2 to the ambient (see appendix 10 of [10]). There is in conclusion a certain amount of external work produced by the ensemble of the Krebs cycles. For each individual or-

ganism there is a great variation between peak performance and average performance. As a general rule we may say that the average external work plus the internal work (metabolism) is of the order of one watt per kilogram.

The total power of the biosphere is

$$\pi_{\text{bio}} = \Phi^{\text{in}} = \Phi^{\text{out}}$$

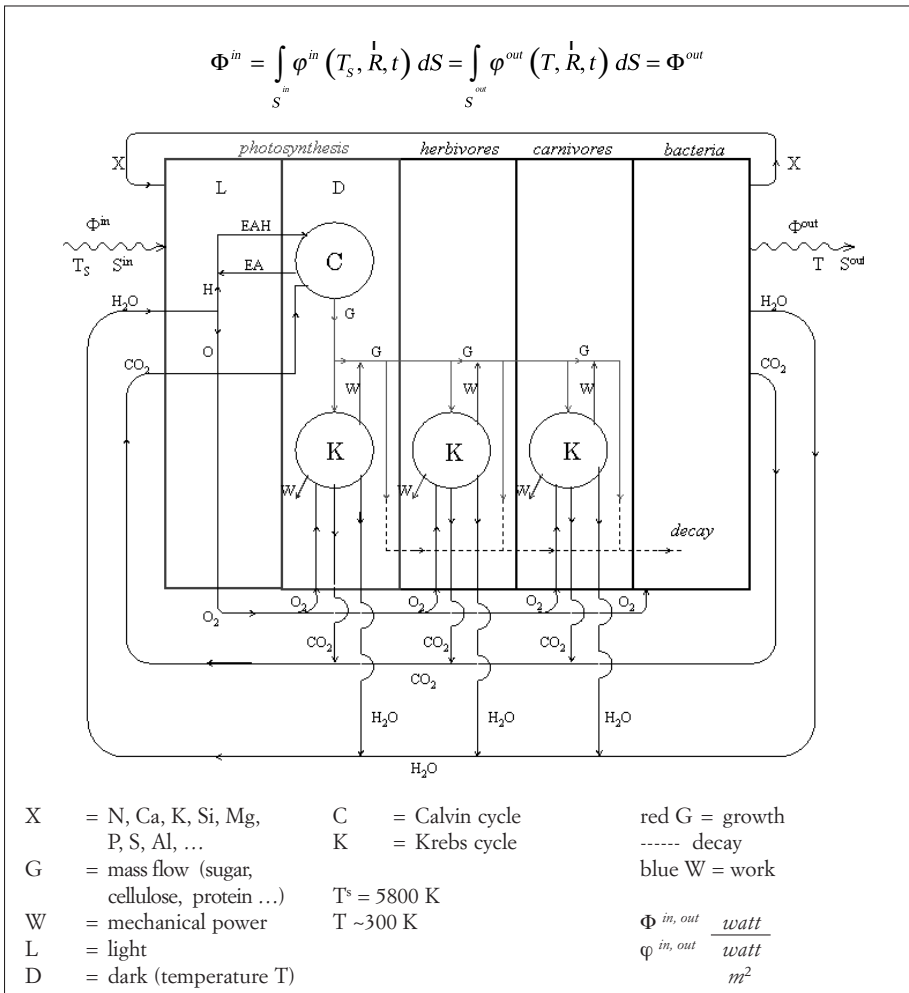


Figure 8.1. Biosphere.

complicated dissipative structure. Such structure is distributed on the surface of the Earth (a thin spherical shell). It involves several million species, and the populations within each species differ by several orders of magnitude. Figure 8.1 shows solely the unidimensional trophic sequence.

The evolution of the human species, the development of knowledge that manifests itself in art and science happened in concurrence with the exploitation of flow energy rather than fossil energy. In particular the largest portion of the energy was extracted from the biosphere, a smaller portion from the inorganic sphere. Civilized evolution means obviously vitality above the level of survival and vitality implies at the same time the stable maintenance of the metabolism (no sudden starvation) plus a certain amount of availability for creative purposes. As the human species is a member of the trophic web, feeding from vegetation and animals comes first. The excess availability in the past came again from the biosphere, work done by domestic animals plus a certain amount of work done by wind. The sum of metabolism plus excess availability, averaged over the day, or over the year, and averaged over the population can be estimated with indirect reasoning because the energy accounting in the past was non existing. The concept of energy (measured in joule) and power (measured in watt) appears only in the nineteenth century. We can take for reference the qualitative estimate:

Power $\pi = 100 \div 150$ watt/person

This value includes food, services,

manufacture, transportation. Notice that peak performances involve much more than 50 watt; nevertheless 50 watt as a time averaged power is a large number.

From Plato to Einstein the power per person did not change significantly from the above value. It is striking the comparison with present day USA calculated power per person:

$$\pi \approx 10^4 \text{ watt/person}$$

The first good property of the biosphere as a resource is its stability of flow. We know that the biosphere is a living control system: this statement comes as a consequence of the experimental finding that the dynamics of the biosphere is immensely more stable than the dynamics of the inorganic sphere.

Next consider the seasonal and daily local variations of the biosphere. These variations have motivated the most ingenuous inventions of man: from grass to hay, from grape to wine, from milk to cheese etc. The shelters for the human beings and the reservoirs for almost everything. Money is *per se* a reservoir, together with the precious metals, the rare and long lasting objects. The biosphere is highly complex and man “needed” to develop a complex intelligence. We may say that, in a certain sense, the biosphere was the friendly teacher of man from the origin of civilization until the end of the nineteenth century: at that time happened a change of mothership: from mother Nature to mother Engine. Appendix VI shows some properties of the organic reservoirs.

Let us now return to the present.

Figure 7.1 is intended for the web of money but after all this figure works equally well to represent a finite elements reduction of the dynamics of fluid motions (the climate) or the interactions of the living species (the biosphere). The dynamical web of money we are considering is powered by the solar radiation therefore the rings of Figure 7.1 must be positioned in the real territory with the climate conditions and the biosphere conditions developed in the course of ages. Evidently house, transportation, manufacture must agree with the local energy inputs and with the local climate. It is the ensemble of activities related to immaterial exchanges that should take men travelling around the global web. Intelligent transport not massive transport.

For science the transition from centralized production of massive

artefacts requiring fossil energy to the inverted situation in which production is local, local material and energy coming from local sources, and going to local needs, is seen not as a tragedy but as a possibility. The arsenal of potential outlets in contemporary science is truly immense. Can we forecast a paradise inhabited by angels? Looking to past history seems that humankind has difficulty in keeping up with the development of science.

For instance if the producer P tries to survive imposing the structure one to many by selling OGM, covered by patent and protected by weapons, which in other words means imposed to the consumers, the disease of web asphyxia would come with us again. This time with unwise manipulations of the biosphere (Figure 8.2).

According to this scheme the Pro-

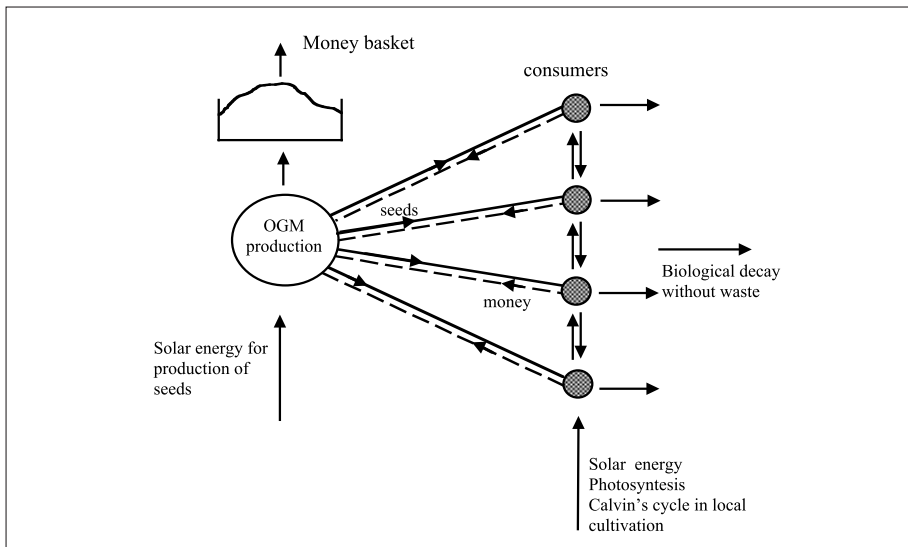


Figure 8.2 OGM network.

ducer becomes direct owner of nature and indirect owner of the consumers [18].

The eternal dualism between knowledge and prevarication is involving more and more problems of global biophysics (science of the biosphere), molecular genetics, and population genetics.

9. The energy input from the inorganic sphere. The main inconvenience of the inorganic energy flow is its variability in space and time. Given for granted the acquisition of the technology of access we have in general that the energy input is irregular, therefore is necessary an equalizer. Variable means that photons arrive at any given surface element of the Earth with a time dependence which is never synchronized with any other surface element; this happens because the spin angular momentum and the orbital angular momentum are not parallel (the days and the sea-

sons). Irregular means that the local transparency of the atmosphere has a chaotic time dependence. Concerning the atmospheric and oceanic motions they have a description which is cyclic if is sampled with large units of volume and time, chaotic if sampled, within such units, with smaller units, those useful for the human scale.

The biosphere is much less chaotic, as observed. The reason is that the living organisms have built in controls that tend to stabilize both their inner individual dynamics and the external interactions among members of their own species and among different species. This ensemble is an extremely complex control system, so much complex that it has touched the imagination of man since ever, to the point of attributing to the biosphere the role of superior being.

Here we show a table of inorganic energy reservoirs:

The extraction and distribution of

<i>Natural</i>	<i>Artifact</i>
Heat content of the Earth's core and mantle. These are fossil reservoirs with different physical properties and are created in the antique process of formation of the planet. The heat released by the radioactive elements should be considered as a reservoir slowly flowing: to fix the ideas, the endogenous heat flow is	<ul style="list-style-type: none">– Dams equalizing the water cycle.– Electric batteries equalizing the input output current originated by wind mills or direct solar photons.– Hydrogen reservoirs where again the primary input is the windmill or the direct photons.– Most interesting of all, the heat stored and released from the inner structure of a thermodynamically controlled house.

energy from coal, petrol, natural gas (organic fossil), is centralized almost by necessity: in fact the fossil reser-

voirs are constituted by large isolated underground domains. The access to these domains is positioned in specif-

ic locations and requires the operation of conceptually simple but technically large or super large machineries. This simple truth is the cause that the possession and control of the fossil energy source is in the hands of few individuals who need to defend their position with a determination that is proportional to the importance of the source itself. Never in past history, namely before the discovery of the fossil petrol, existed a comparable concentration of money and violence.

The extraction of energy from the natural uranium reservoir is more complicated with respect to the case of oil. The complex nuclear technology is protected by patents, is private property rather than common knowledge; moreover the international treaties on military non proliferation are imposed by force rather than by virtue of reciprocity.

The extraction and distribution of energy from direct solar photons and from indirect fluid motions is not localized. Centralization of operation in this case may follow from choice. One choice is large areas covered by solar collectors, large windmill fields, large networks of the energy flow to the end users.

The opposite choice is operation of collection, storage and use by local communities.

Third is a contamination of the two, that can be wise or unwise.

10. Entropy production and web performance. In this chapter we compare the fossil fuel society of the type “conveyor belt” (see Figure 10.1) and the solar flow society of the

type “web” (see Figure 10.2).

The first describes the present state, the second is the future final state. The transition implies profound changes of the social structure and these changes may be smooth or violent.

The purpose of this section is not the presentation of possible scenarios but simply the discussion of the concept of efficiency in these two extreme cases.

Figure 10.1 Fossil fuel society, type “conveyor belt”.

In this scheme the society is constituted by a producer P and a consumer C.

They are the interface between the upper part of Figure 10.1, the Economy, the reign of wealth and poverty, and the lower part, Physics, or the reign of the laws of nature.

Meaning of P and C. The word producer used in this paper is equivalent to the word corporation, which is “person” according to the American legislation. Giving the legal right to enjoy the individual freedom of behaviour, profit, ownership, to a giant has far reaching asymmetric implications. For instance the patent, which is the recognition and protection of an intellectual achievement (invention) tends to become ownership of nature (more precisely of crucial experiments fundamental for further scientific knowledge). This induces a contamination of law and science that is additionally open to a third party, the authority used to impose the obedience to the patent rights in various countries. (Try to own a patent if you are a genius but unprotected). Fur-

A. The conveyor belt

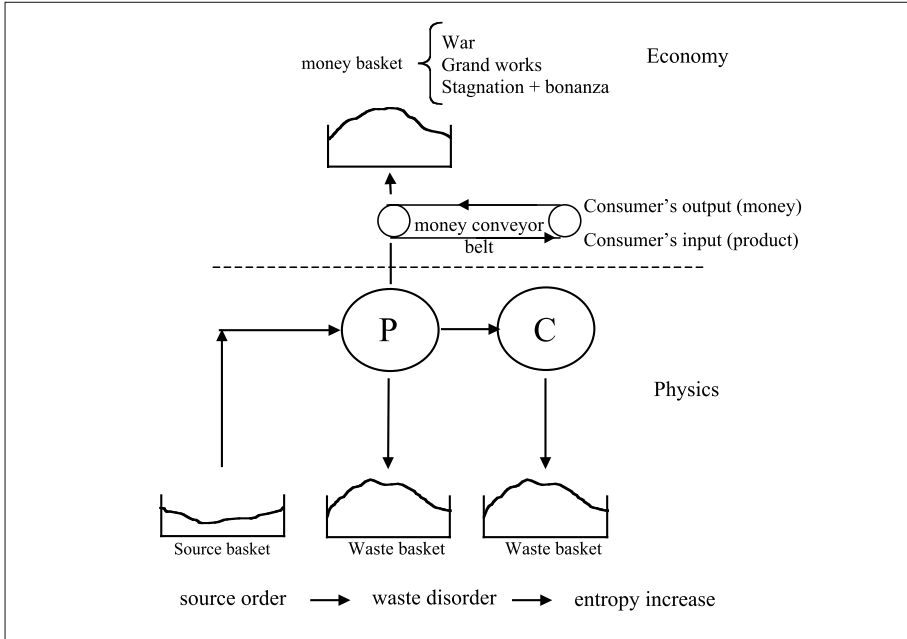


Figure 10.1 Fossil fuel society, type “conveyor belt”.

thermore the opposition to a corporation coming from the people, or from another State, tends to be rejected as a violation of a private initiative, so that the opposition is qualified as common crime rather than reaction to an artefact disproportionate force. The well being of a society defined by history, evolution of language and culture, becomes dependent on the free benevolence of one or few corporations.

Meaning of efficient economy. The economy is efficient if the money basket is filled at a constant rate (exponential growth). This implies that the conveyor belt must turn as fast as possible and this happens if the op-

erating wheel C (the faceless community of the consumers) turns fast and the size of the community C increases.

Physical implications. The operation of the belt induces a unidirectional pathway, shown in the lower part of the figure. The direction is from source basket to waste basket. Depleting a natural source and producing an artefact waste means producing excess entropy. The word “excess” specifies entropy added to the entropy produced by the natural dynamics, which is governed by non equilibrium irreversible thermodynamics [20].

According to this scheme the rate

of filling the money basket is proportional to the rate of consuming fossil energy.

We have the following equations:
 money / unit time = α petrol / unit time = β waste / unit time = γ excess entropy / unit time where evidently α , β , γ are dimensional constant factors.

The above relationships are crude approximations, have been observed over the years and are well known.

The outcry: energy is needed, consumption cannot stop, is the popular way of reading the above scheme.

B. The web. The dynamics of the biosphere does not function according to this scheme. The photosynthesis works in such a way that source and waste coincide: they are the molecules of H_2O and CO_2 in perennial circulation from synthesis to decay, forever. In chemical language there is reduction on the incoming photons interface and oxidation on the outgoing photons interface. These are shown respectively on the left hand side and the right hand side of Figure 8.1. The overall cycle contains a com-

plex chemical disequilibrium, in global stationary state. There is no excess entropy production, only the right amount of entropy. The biosphere is an open dissipative structure, similar but much more complicated than the purely deterministic dissipative structures, like the atmospheric and oceanic motions, which are studied since a longer time and are better known [19, 20]. The energy that the living plants receive from the solar photons is re-emitted in the form of cooler photons and the two radiation fluxes balance: entropy is produced in the process and the global biological structure is maintained with a remarkable stability. The biosphere is a standing web and its “performance index” is one, no sinks, no losses.

A society functioning in harmony with the biosphere is described in Figure 10.2.

Energy extracted from the organic dynamics.

1. Energy returned to the organic dynamics as recyclable organic waste incorporated along the lines of the trophic chain according to

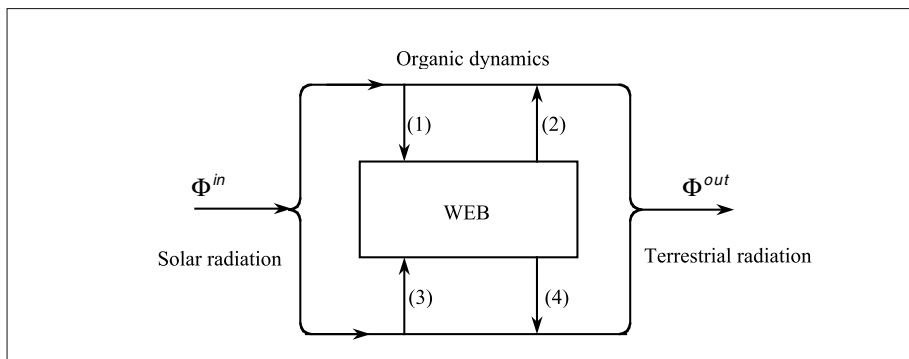


Figure 10.2 Solar flow society, type “web”.

- the scheme of Figure 8.1.
2. Energy extracted from the inorganic dynamics.
 3. Energy returned to the dynamics after the extraction cycle is performed.

With inorganic dynamics we mean here irreversible fluid thermodynamics. Energy is available if there is disequilibrium; nothing in fact can be extracted from an ambient at P (pressure) and T (temperature) fixed. Disequilibrium can be thermal and kinetic. In both cases the extraction of energy implies a cycle: a Carnot cycle, or a windmill cycle. It follows that within a certain local domain, open to the surrounding, we have:

$$\begin{array}{ll} \text{Carnot} & Q^{\text{in}} = W + Q^{\text{out}} \\ & W \text{ is work, } Q \text{ is heat} \\ \text{Windmill} & E^{\text{in}} = W + E^{\text{out}} \end{array}$$

W is work and $E^{\text{in,out}}$ are respectively kinetic energy before and after the windmill (or sail).

Windmill cycle means that the fluid flow is conserved.

W enters in the web as excess energy, does its job and ultimately ends up in dissipation, namely heat added to the outgoing terrestrial radiation.

In this scheme first of all there is no conveyor belt, no money basket, and also no waste basket. P and C are replaced by the complex web structure itself. Where is then the difference between a human society and any other population of animals? Where is gone the well being of civilized life? We need to define a performance index for the human web, such that a certain amount of excess energy is taken into account. This is a

problem of complex system dynamics not unknown to physicists and mathematicians and biologists and ecologists, even familiar to farmers all over the planet. No one is interested in prospects of poverty. On the other hand there is nothing similar to a return to the pre industrial way of life, because the evolution is irreversible. In those eras the usable Earth was all the time increasing, the geographical discoveries, and the desired excess energy was acquired by a human population that was much smaller, and in fact correlated to the territory. In conclusion the future needs, and must invent, something new.

The concept of access to natural resources without violating their rate of reproduction belongs to the domain of control theory in the special case of passive controls [21]. The general ideas are known, but the problem is to find how the well being of a given web can be defined, produced, maintained, and maximized, obviously within certain boundary conditions. Housing and transportation, which are energivorous today, need to be redesigned, and all this makes sense, and the good science has much to say.

This transition is worrisome and perhaps fatal to those who have a passive role in the machinery of the present bonanza. But this is a transient that cannot be procrastinated, and this truth is perfectly well known. It is an external cause acting on the evolution of the human species, and this implies bifurcations, with choices that may be winning, or not, articulations of the intelligence that will survive, or fail.

Conclusion. The nuclear weapons are

in the hands of men who, by profession, are educated to operate their delivery to target. To this purpose they must control a network including fabrication, maintenance, protection of the depositories, plus the continuous updating of the carriers, which are ballistic missiles, unmanned air planes, small rockets, or, maybe, space stations. This implies a huge and expensive network.

The making of nuclear weapons has been told in important books [22]. The detailed technologies are accessible to few specialists. The unmaking of the nuclear armies might come by multilateral balance, by moral rejection, by war.

The transition to solar energy is a process that cannot be examined as an abstract issue disjoint from the problem of the actual military balance of power. The presence of nuclear weapons should be considered as a sort of initial condition for the second half of the history of the human species, the era after 1945. The transition to solar energy implies in fact a rethinking of the concept of territorial ownership both at ground level and at the height of the space stations that, according to certain ambi-

tious projects, could be used to intercept the solar radiation flux.

The fact that the solar flux is distributed over the terrestrial surface rather than concentrated as it is for the fossil resources does not imply that solar energy is “democratic” rather than “privileged”.

In the past the solar radiation was used locally according to the indirect process: radiation – photosynthesis – agriculture – wealth. The solar energy was a natural resource used in a natural way. Modern technology can change all that. The technology of OGM changes the local agricultural life into a centralized production business. Analogously the energy extracted from the fluid motions with giant dams and giant windmill fields is a centralized business. The same is true for the various ways of converting photons into electric energy.

Military control of land, ocean, sky can be worse than the present day control of the oil fields and oil routes.

The conclusion is that the real issue is not technology but something much more general, that is the invention of a new concept: the non energivorous well being.

¹ In this book the explanation of history in terms of money is clear, is axiomatic – deductive, fascinating. Question: the dynamics of money explains the causes of the human events, or explains some causes, or the cause of some events only? If the relationship cause-effect makes sense it has to be complete, and within a theory, otherwise is not an explanation but only a description. The idea that money “explains” presumably was born at the time of the Italian renaissance, developed to

the level of theory with Adam Smith, and became truth only in the last century. At this point economic theories and physics are disjoint.

² The *lazzari* are *humillimus plebs* defined by exclusion: are not nobles, are not civil servants, are not merchants. The name appears in 1634, 153 years before the *Italian travel*. See B. Croce, *Un paradiso abitato da diavoli*, a collection of essays. [15] Goethe talks of a stable well known phenomenon.

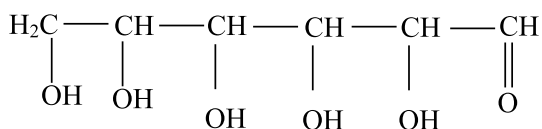
Appendix I

Carbohydrates, sugar, polysaccharides

Details of A

CARBOHYDRATES $C_x(H_2O)_y$

- SUGAR (simpler carbohydrates):
D-GLUCOSE (also called DEXTROSE) $C_6H_{12}O_6$



FRUCTOSE (fruit sugar)

MALTOSE (malt sugar)

LACTOSE (milk sugar)

SUCROSE (combination of glucose and fructose) $C_{12}H_{22}O_{11}$

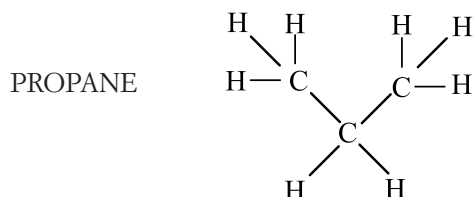
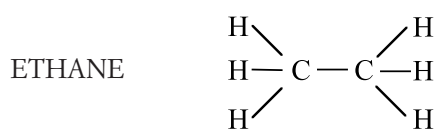
- POLYSACCHARIDES (complex carbohydrates): $(C_6H_{10}O_5)_x$
STARCH (occurs in plants)
GLYCOGEN (occurs in blood and internal organs of animals)
CELLULOSE (structural element for plants)

Appendix II

Methane and other alkanes

Details of B

METHANE CH_4 First member of methane series, *alkanes*
 Natural gas \rightarrow 85% methane
 Methane combustion: $\text{CH}_4 + \text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{C}$



ETHANE $\text{C}_4 + \text{H}_{10}$

GASOLINE C_7H_{16} to C_9H_{20} (heptane-to-nonane mixture)

KEROSENE $\text{C}_{10}\text{H}_{22}$ to $\text{C}_{16}\text{H}_{34}$ (decane-to-hexadecane mixture)

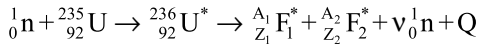
Appendix III

Fission reactors

$\left. \begin{matrix} {}^{238}\text{U} \\ {}^{232}\text{Th} \end{matrix} \right\}$ abundant in nature

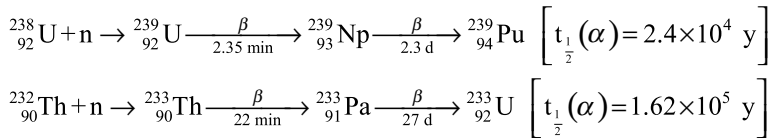
${}^{239}\text{Pu}$ toxic – useful for both fission and fusion bombs

Thermal reactor with enriched uranium ${}^{235}\text{U}$



[* means excited state]

Breeder reactors



The abundant nuclei ${}_{92}^{238}\text{U}$ and ${}_{90}^{232}\text{U}$ can be used in breeder reactors. The difference between breeder and thermal reactors is structural. The neutrons operatives in the first step of the above reaction are fast rather than slow, as in the thermal reactors.

Appendix IV

Fusion reactions

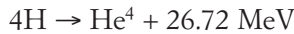
Possible fusion reactions in controlled thermonuclear reactors

Fusion reactions (DT); $T \geq 4$ keV	
$D + T \rightarrow \alpha + n + 17.6 \text{ MeV}$	$T(D,n)He^4$
Fusion reactions (DD); $T \geq 34$ keV	
$D + D \rightarrow T + p + 4.03 \text{ MeV}$	$D(D,p)T$
$D + D \rightarrow He^3 + n + 3.27 \text{ MeV}$	$D(D,n)He^3$
Fusion reactions (DHe); $T \geq 100$ keV	
$D + He^3 \rightarrow \alpha + p + 18.3 \text{ MeV}$	$He^3(D,p)He^4$
Fusion reactions (HLi), (DLi), (HB)	
$Li^6 + H \rightarrow He^3 + \alpha + 4.02 \text{ MeV}$	$Li^6(p,\alpha)He^3$
$Li^6 + D \rightarrow Be^7 + n + 3.4 \text{ MeV}$	$Li^6(D,n)Be^7$
$Li^6 + D \rightarrow He^3 + n + \alpha + 1.8 \text{ MeV}$	$Li^6(D;n,\alpha)He^3$
$Li^6 + D \rightarrow Li^7 + p + 5.0 \text{ MeV}$	$Li^6(D,p)Li^7$
$Li^6 + D \rightarrow T + p + \alpha + 2.6 \text{ MeV}$	$Li^6(D;T,p)He^4$
$Li^6 + D \rightarrow 2\alpha + 22.4 \text{ MeV}$	
$B^{11} + H \rightarrow (C^{12})^* \left\{ \begin{array}{l} \alpha \\ Be^8 \rightarrow 2\alpha \end{array} \right\} + 8.7 \text{ MeV}$	$Li^6(D,\alpha)He^4$
	$B^{11}(p,2\alpha)He^4$

Light nuclei are abundant in the Universe. They are the fossil of the big bang [23, 24]. The fusion reaction listed above are fast but difficult to confine.

The fusion reactions existing in the Sun on the contrary are slow.

The Bethe hydrogen cycle has balance



This cycle is the slowest reaction known and this is why the Sun has such a long life.

Given appropriate conditions created by complex artefacts fusion is explosion.

The fusion reaction in the H-bomb is the first in the 4th box, lithium.

After sixty years of efforts controlled thermonuclear fusion reactors do not exist yet.

Appendix V

Reactor's safety

In the hands of scientist who know the underlying physics and indicate the appropriate technical solutions for construction and maintenance, nuclear fission reactors are safe [25]. In the hands of incompetent or ill intentioned men they are extremely dangerous. In particular, the disposal of the reactors and their sites after operation requires money and is not clear where this money should come from.

The following table is taken from *Energy Vol. III: Nuclear Energy and Energy Policies*, edited by Penner [8], and describes the safety *during operation*.

Estimated numbers and individual probabilities of occurrence of fatal accidents by various causes in the U.S. during 1969.

Accidents involving	Number of accidents during 1969	Approximate individual risk of suffering an acute fatality during the year(a)
Motor vehicles	55,791	3×10^{-4}
Falls	17,827	9×10^{-5}
Fires and hot substances	7,451	4×10^{-5}
Drowning	6,181	3×10^{-5}
Poison	4,516	2×10^{-5}
F rearms	2,309	1×10^{-5}
Machinery (1968)	2,054	1×10^{-5}
Water transport	1,743	9×10^{-6}
Air travel	1,778	9×10^{-6}
Falling objects	1,271	6×10^{-6}
Electrocution	1,148	6×10^{-6}
Railways	884	4×10^{-6}
Lightning	160	8×10^{-7}
Tornadoes	91 ^(b)	4×10^{-7}
Hurricanes	93 ^(b)	4×10^{-7}
All other	8,695	4×10^{-5}
All accidents	111,992	6×10^{-4}
Nuclear accidents for 100 reactors	0	2×10^{-10}

(a) Based on the total US. Population.

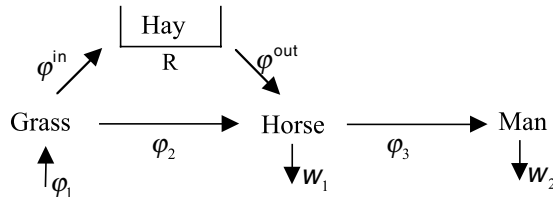
(b) Average for the period 1953 to 1971.

This is a perfect example of shadow information. The real danger is the war for the control of nuclear markets, including construction of reactors, uranium minerals extraction and fuel preparation, power plants protection, electric energy distribution, waste disposal. The nuclear market is not at all democratic.

Appendix VI

Organic reservoirs

1. Organic energy flow. The dynamics of the biosphere in the stationary state is an ensemble of cycles. This is so because the input of the dynamics is photons and the output is photons again, therefore the biochemical dynamics, that involves mass, cannot be anything else than cycles. A reservoir is something that can be filled, held in standby, used, and refilled again. If this process performs a cycle (which is necessary, otherwise the biosphere is violated) it follows that the reservoir is nothing else than a time delay device. Consider the cycle grass-hay-horse-man.



The grass is forced by the solar flux φ_1 (watt). The flow of grass goes in two channels, φ_2 , directly to the horse, and φ^{in} to the reservoir R (hay, joule). From R there is the outgoing flux φ^{out} to the horse. In this way the flow received by the horse can be kept constant despite the oscillations of the solar input. The horse produces the waste W_1 (watt) plus the work φ_3 (watt) delivered to man. Finally man uses φ_3 and delivers the waste W_2 (watt). In real life this cycle is interconnected with a multitude of other cycles and relative delays. This is the complexity of the natural dynamics of societies non violating the biosphere. Roughly speaking this is the dynamics of humankind from origin until the industrial modern era.

Notice that both the inorganic sphere and the biosphere contain natural reservoirs, or natural delays. The most impressive inorganic delay is the triplet ice, water, water vapour that controls the water cycle. Other organic delays are more subtle and more difficult to understand.

2. Organic fossil energy. In contrast with the above complexity of the reservoir-delay systems tuned with the biosphere, the reservoirs operating with organic fossil fuels are not tuned with the biosphere for the simple reason that they operate according to a one directional pathway: extraction \rightarrow distillation \rightarrow storage \rightarrow delivery to end users \rightarrow burning \rightarrow entropy production, end of line.

No matter how huge are the drills, the refineries, the tankers, the pipelines, their dynamics is immensely simpler than the dynamics of the artefacts that man has developed in the past, when harmony with nature was necessary.

The weakness of the fossil fuel social and economic life is due to its absence of feedbacks and related mechanisms of repair. Actually the present consumer's eco-

nomic theory excludes even the existence of such concepts because physics and biophysics are boundary conditions and not variables of the theory.

The gasoline pump station will be studied by the future archaeologists in the same chapter and together with the monoliths of the Pacific Ocean Easter Island.

Appendix VII

Inorganic reservoirs

1. Inorganic energy flow. The most important reservoir of inorganic energy related to flow is constituted by the gravitational potential energy of water. In fact the water cycle moves continuously H_2O molecules in and out the three phases ice, liquid, vapour keeping the total number of molecules fixed. If there is a stationary state of the global dynamics the annual average of the mass of ice, of liquid, and of vapour is also fixed. The phase transition vapour-liquid happens at different points of the terrestrial surface, corresponding to different values of the gravitational potential of the Earth. This is why rivers flow toward the equipotential spherical surface of the Ocean. This flow is kinetic energy, and can be utilized with high efficiency. A basin in the way of the flow to the Ocean can be natural, lake, or artificial, and in both cases is an energy reservoir. These are the most important energy reservoirs from flow, and used since ever. The global power of the water cycle is enormous, is about one third of the solar energy reaching the ground.

2. Inorganic fossil, namely nuclear

Man made. The nuclear fuel (unlike coal, gas, petrol) does not exist ready made in nature; it needs to be manufactured with complicated processes. Nevertheless the manufacture of the nuclear fuel, its use in nuclear reactors, and the distribution of the electric energy produced is the easy part of the entire process. In fact this can be considered “job accomplished”. The difficult part comes later. The products of the nuclear combustion are isotopes that do not exist in nature for a simple reason: these isotopes decay by spontaneous emission to stable nuclei; the decay half lives are short on the cosmological timescale, long on the human timescale. It follows that if they existed at the time of accretion of the Earth by now they are all decayed. On the contrary these isotopes created by man, as long as the human history is concerned, constitute a standing reservoir of radioactive nuclei. These are the nuclear reservoirs created by man, not by nature. The dismissed power plants are also analogous reservoirs. So, we have something to think about: abandoned reservoirs or appropriate repositories according to the pure dictum of physics? See reference [25].

This is not an unsolvable problem but certainly is a problem.

Natural. ^{235}U has half-life about one hundred times shorter than that of ^{238}U which is of several billion years. This is why ^{235}U is much less abundant (about one per cent) and why both isotopes are weakly radioactive. The mineral deposits are constituted by uranium oxide U_3O_8 . The resources are classified as reasonably assured and easy to mine, class I, or less easy, class II. The following tables are taken from Hans Bethe and David Bodansky, *Energy supply*, chapter 11 in ref [26].

Table VII.A

	I	II
USSR and East Europe		4.2
Australia	0.9	4.8
USA	1.3	3.3
South Africa	1.0	2.1
China		2.1
Canada	0.7	1.1

The unit is one million tonnes of U.

Table VII.B Orders of magnitude of the global fossil resources.

Nuclear	6.0×10^3 EJ	if breeder
Nuclear	6.0×10^3 EJ	non breeder
Oil	8.5×10^3 EJ	
Coal	2.5×10^4 EJ	

1987 estimates, averaged over various authors.

EJ = exajoule = 10^{18} joule.

The binding energy of the couple Earth-Moon is

$$B = 3.85 \times 10^{10} \text{ EJ}$$

where B is:
$$B = \frac{1}{2} \gamma \frac{M_{\text{Earth}} M_{\text{Moon}}}{d_{\text{EM}}}$$

Appendix VIII

Nuclear technology

There is talent and money invested in the making of a movie; the return comes from the show market. Advertising the movie contributes as well and also that money must return. Similarly for the making of a racing car; the talent is technological here, and the market does not respond to the racing car itself but to the brand name of the corporation that has made the investment.

The largest investment of all has been the nuclear technology; the correspondingly immense direct return did not materialize yet. One way to minimize the missed return is to maximize an indirect effect, the geopolitical dominance that a nuclear powerful Nation can exert. But this is not equivalent to the expected return from the direct use the nuclear energy industry. When the cold war ended the funding of the nuclear technology diminished. Then, the concept of terrorism has helped other competing areas of technology. The nuclear reactor's market remains dormant, in particular the breeder route. One can hope that the reason is prudence, the perception that having too much plutonium around creates risk. Nevertheless the ultimate reason why the breeder is not developed is unknown. Research and development for the fusion weapons has been reduced after the atmospheric test ban, and the fusion reactor program remains on the waiting list, so that plasma physics attracts less students. This situation is unstable and the innumerable nuclear patents remain not seen but ready to claim their potential rights.

For the banker, movie industry, automobile industry and nuclear industry are all opportunities.

Appendix IX

Complex systems

Before the computer

Deterministic systems, physics. There is a basic component, simple fundamental dynamical equations containing the minimum number of parameters. System means several components in interaction.

$N = 2$ Defines simple system. Analytic solution in closed form exists for the two body problem in newtonian gravity and in quantum mechanics, the hydrogen atom.

$N = 3$ Numerical solution of special cases of the three body problem in astronomy.

$N > 3$ Defines complex system. Perturbative calculations in astronomy and in quantum mechanics of atoms, molecules and nuclei.

$N \rightarrow \infty$ Statistical methods for the description of equilibrium and for the approach to equilibrium: Boltzmann transport equation for ensembles of molecules, 1898; transport equation for plasma in the stars, A. S. Eddington, 1930.

Finalistic systems, biology. Individual organism, with particular morphology and generation process: the individual is generated, lives, and dies. Concept of species. Complex is the web of species. Concept of evolution within the web.

After the computer, von Neumann 1949

Deterministic systems. $N = 64$ Molecules with non linear two body interaction: the work by Fermi, Pasta, Ulam 1955, using the Maniac I computer. The discovery that thermalization from an initial condition is not an easy process: presence of dynamical structures. From that time complex became almost synonym of molecular physics, plasma physics, astrophysics and astronomy. In general dissipative structures, governed by irreversible equations of motion.

A special case is game theory, von Neumann, models of economy.

Finalistic systems. Complex system is the domain of molecular genetics, the macroscopic network of Lotka-Volterra coupled systems, the non equilibrium physical ambient of the biosphere, the biosphere itself. In general ecophysics is science of complex systems.

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