ENERGETICS AND THE CAPACITY OF GEOBIOSPHERE

against population and self-renewability of the Earth

Czesław CEMPEL[1]
Institute of Applied Mechanics, Poznań University of Technology

Summary

The work makes use of a concept of geobiospheric emergy balance in various variants of the use of its resources. Only renewable and available forms of energies are taken into account. The data were compared to four emergetic standards of human living in the Earth. The result of such an estimation of the number of people leads to an opinion that extreme data (0.3 and 30 billion) should be eliminated and new technologies should be sought as soon as possible, making use of whole resources of renewable energy, enabling the use of pure energy rising no damage to the environment.

1. Introduction

Condition of our Mother Earth already in the 1960s became a subject of concern of the people concerned about the state of the whole world system. It became a subject of research upon defining of an ecological system in the significant work of R. Carson, **Silent Spring** [Carson62]. According to recent definition **eco-system is a self-renewable, multi-level balancing processes of matter, energy, and information transformations** [Lenart02], arising and adapting to each other within the compass of millions years. In order to embrace the whole set of geobiospherical problem considered as an eco-system a common measure of activity and potential is necessary, enabling balancing of the streams of these values. Such a measure, based on the concept of energy, was defined in the 1970s [Odum86], when the system balances of primary energy coming from the Sun were calculated for the first time. It became obvious that the energy transforms many times (at many levels) and, moreover, one Joule (J)[2] of solar energy and 1 **J** of combustion energy derived from wood should not be directly equated. A transformation cost (coefficient) of transformation from one energy type to another should be added and thus all the types (levels) of energies in eco-system should be converted to primary energy coming from the Sun. This proposal was presented for the first time by T. Odum, who defined a new value describing the equivalent energy, the so-called emergy [Odum86], [Odum 96]. **Emergy** is defined as available energy of one type (level) used for transformation or (directly or indirectly) for manufacturing of a product or rendering a service. A unit of such defined value is **emjoule** of solar energy, abbreviated **sej** (solar emjoule). In order to converting between all the levels of energy forms of the ecosystem a so-called **transformity** of every ecosystem level should be defined. It is defined as quantity of emergy of the lower level falling to energy unit obtained at given level. For example, in order to obtain 1 J from wood 4000 **sej** are needed. Thus, transformity of wood in such ecosystem amounts to 4000 sej/J, while transformity of solar energy absorbed by the Earth amounts to **unity**. Making use of such prerequisites the main streams of renewable energy supplied to the Earth (solar radiation, wind, abyssal heat) were converted to **sej**, as well as the emergy if main ecosystem resources and their products, like petrol, minerals, wood and others [Odum96], [Odum00]. The calculations were made for particular states of the USA and some other countries of Europe and the world, inclusive of Poland. This enabled to determine emergy values falling yearly to one inhabitant[3] Knowledge of total balance of the emergy enables estimating of possible number of population of the Earth, in accordance with the type of

[1] ul. Piotrowo 3, 60-965 Poznań, fax; 061.6652307, email: Czeslaw.CEMPEL@put.poznan.pl
[2] Joule (abbrev. **J**) is a unit of energy equal to the work of the force of one Newton (N) at the distance of one meter.
[3] The data correspond to the 1980s.

used emergy (renewable/non-renewable ratio) and emergetic standard of living of inhabitants of the Earth, e.g. comparing the standard of India with the one of Western Europe. This is a direct goal of the present considerations and calculations. A further goal consists in formulation of additional knowledge and information useful to eco-comunity of the Earth, concerned of the future. This should allow to answer in what direction aims the humanity (consciously or not). According to Author's knowledge, it is a first estimation of such a kind, therefore might be charged with various mis-statements. I would be much indebted for possible information and discussion.

2. Energetics of geobiosphere

The geobiosphere of the Earth, considered as an open system, is supplied with energy from three external resources: absorbed solar radiation, abyssal heat coming from inner layers of the Earth, and the energy of tide phenomena, due to the Moon and the Sun. The energy of absorbed solar radiation heats main components of the system: the atmosphere, the surface of the Earth and the oceans (Fig. 1). Moreover, the surface of the Earth is heated by the energy coming from abyssal sources and the heat due to natural radioactive decay. All the energy resources coming to the surface of the Earth, being the place of civilization development, are called **renewable resources**, due to very long time of their almost unchanged action, as compared to the duration of civilization in the form we know at present. Moreover, civilized humans learned to make use of energetic resources and materials available in the upper layers of the mantle of the Earth, like ores, mineral, petrol, which are of **non-renewable character**.

Every transformation of the primary energy to its other forms, measured in the terms of emergy, is always connected with losses, often amounting to considerable fraction of the primary energy. The losses are also considered in the above defined coefficient of inter-layer transformation - the transformity. Moreover, the **civilization** subsystem also exerts its effect, usually of destructive character, on each of geosphere subsystems. The whole discussed system of supplying and emergetic interactions is shown in Fig. 1.

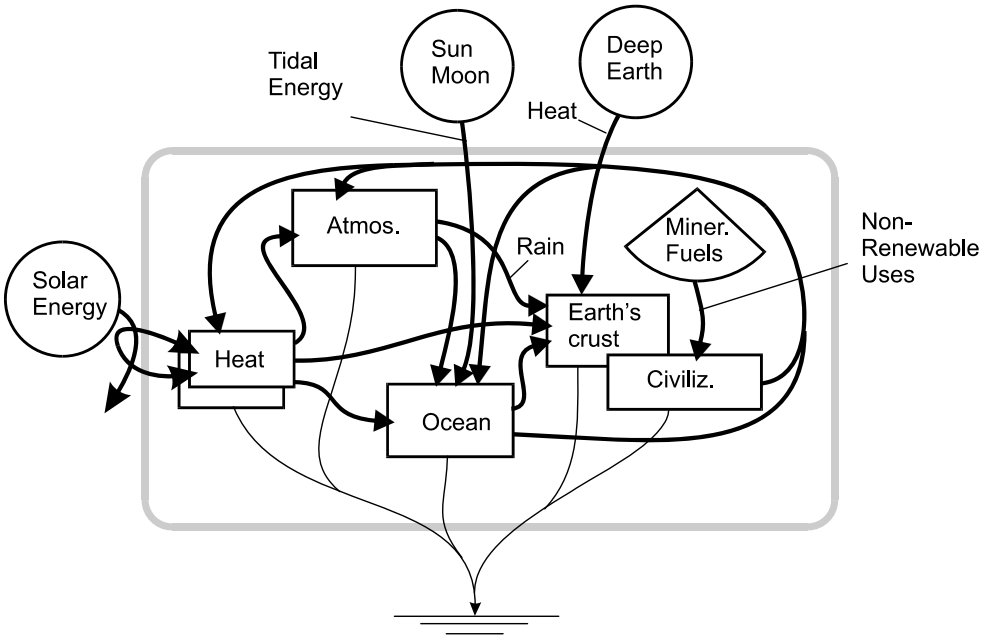

Fig. 1. Sources of energy in geobiospheric system and energy transformation net [Odum00,r1]

This rough picture of emergetic balance of geobiosphere (as in the figure) may be improved giving more detailed values related to main external and internal sources. Table 1 provides the capacity of renewable external sources reaching the system of the Earth.

Table 1. Yearly emergy supply to geobiosphere [Odum96,t3.1]

No	Input & unit	Energy stream **J/per annum**	Transformity. **sej/J**	Energy stream **Sej/per annum**
1	**Insolation, J**	3,93 x E24	1	3,93 x E24
2	**Earth's inside heat, J**	6,72 x E20	6055	4,07 x E24
3	**Tidal energy, J**	8,515 x E19	16.842	1,44 x E 24
	Total - OE =	-	-	**9,44 x E 24**

Note: New designation of exponent numbers, e.g. – **E3 =10^3.**

The Table clearly shows that maximal contribution of emergy stream in the geobiosphere system comes from internal heat of the Earth, insolation contributes to it in smaller degree, while the energy of ocean tides is the least component. Total stream of renewable emergy, according to this estimation, amounts to: **OE=9.44 ·10^{24} sej/per annum**

Figure 1 also shows that our civilization makes a ruining use of non-renewable resources of the Earth [Brown01], i.e. petrol, ores, woods, lands, and others. Total balance of annual cpnsumption of the resources, according to the data of British Petroleum [BP97], cited after the Odum's Handbook [Odum00,t3] is shown in Table 2.

In accordance with these data we use twice as much of non-renewable resources of the Earth (**NE=20.46 E24 sej/per annum**) as compared to total amount of the renewable resources (c.f. **OE**). On the other hand, maximal amounts of non-renewable emergy are represented in decreasing order in the following forms: petrol, coal, gas, nuclear energy, land erosion, wastage of ores, minerals, and woods. These are huge streams of wasted geobiospheric emergy. Moreover, it should be noticed that the first two of them are related to considerable emission of pollution in the forms of CO_2 and NO_x, inducing further degradation of geobiosphere.

Table 2. Annual consumption of renewable and non-renewable emergy resources acc. to Odum's estimation [Odum00,t3]

No	Input & unit	Input energy **J/per ann.**	Emergy/per a unit **Sej/unit.**	Em-power **E24 sej/per ann.**
1	**Renewable emergy** (**OE** table 1)	-	-	**9,44**
2	Petrol **J**	1,38 E20	5,4 E4	7,45
3	Natural gas (petrol equivalent) **J**	7,89 E19	4,8 E4	3,79
4	Coal („ ”) **J**	1,09 E20	4,0 E4	4,36
5	Nuclear energy **J**	8,60 E18	2,0 E5	1,72
6	Woods, trees (loss) **J**	5,86 E19	1,1 E4	0,64
7	Lands (erosion) **J**	1.38 E19	7,4 E4	1,02
8	Phosphate (fertilizers) **J**	4,77 E16	7,7 E6	0,37
9	Limestone **J**	7,33 E16	1,62 E6	0,12
10	Metal ores **g**	993 E12**g**	1,09 E9 **sej/g**	0,99
---	Total non-renewable em-power (**NE**) **Total em-power balance (CE)**	------ ------	----- (sum 2-10) ----- (sum 1-10)	20,46 **29,90**

Note: Emergy stream measured in time unit is referred to as em-power.

3. Emergy consumption for human life purposes - living standards - living with dignity

There are available estimations of em-power coming from outside to the geobiospheric system designated as **OE**, as well as the em-power produced by our civilization from non-renewable resources (**NE**). Diversification of living standard of peoples of the world is considerable. Comparison of such regions as India, Europe, and United States provides significant indications. For many of the countries annual emergy demand was estimated (in 1980-87) per a citizen [Odum96,t10.8]. These estimations are shown in Figure 2, which was drawn out on the grounds of the data. The Figure and our knowledge enable assuming that emergy consumption and standard of living of the country are significantly correlated, except for tropical and equatorial countries where solar energy supply is important and not fully utilized, while exceptional emergy consumption in Australia is a result of living standard and insolation. In order to formulate further estimations some emergetic standards of human living may be assumed, as in Table 3.

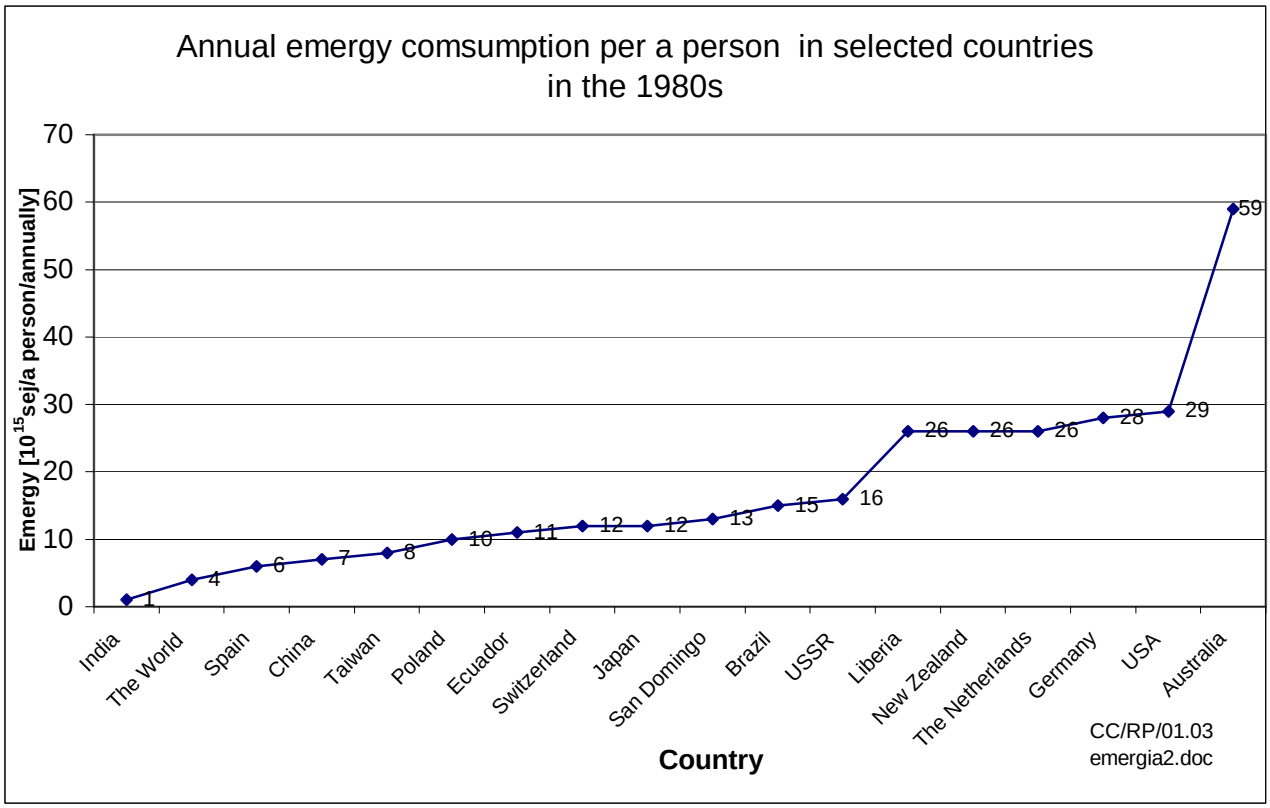

Fig. 2. Annual emergy consumption in different countries of the world in 1980-87, acc. to Odum [Odum96,t10.8].

Table 3. Exemplary standards of annual emergy consumption per inhabitant (acc. to Fig. 2).

---	**Emergetic standard of living**	**x E15 sej/ per person/per annum**
1	India – extreme poverty, crowding	1
2	The World	4
3	Poland	10
4	Western Europe (Germany) - prosperity	28

Table 3 allows to conclude that the spread of living standard levels in the 1980s was equal to 1 to 30 ratio. Nowadays this ratio should be presumably considerably greater, but this is not a subject of the present consideration. A goal of **every human being** is **living with dignity**, but what does it mean against the data of the Table 3? Can we assume that the life of an ordinary inhabitant of India is of appropriate level?. Could the life level of an ordinary inhabitant of the world be considered as adequate, while 1.3 billion people are able to expend less than one dollar daily [Population02], the same number of people having no access to running water? The problem is not simple and should be considered in term of many variants, as it is a case in the following point.

4. Earth population variants

Above are defined the estimations of renewable emergy stream of the Earth (**OE=9.44 E24 sej/per annum**), similar estimation of non-renewable emergy stream (NE=20.46 sej/per annum) and total emergy stream **CE=29.90 sej/per annum**. Assuming for example four living standards on the Earth, according to Table 3, one can estimate earth population related to each of the standards and assumed **OE** and **CE** emergy streams. This is demonstratively shown in Figure 3, with appropriate population numbers corresponding to each of the variants, calculated by division of the emergy available on Earth by the emergy required per person for a given standard level (Table 3).

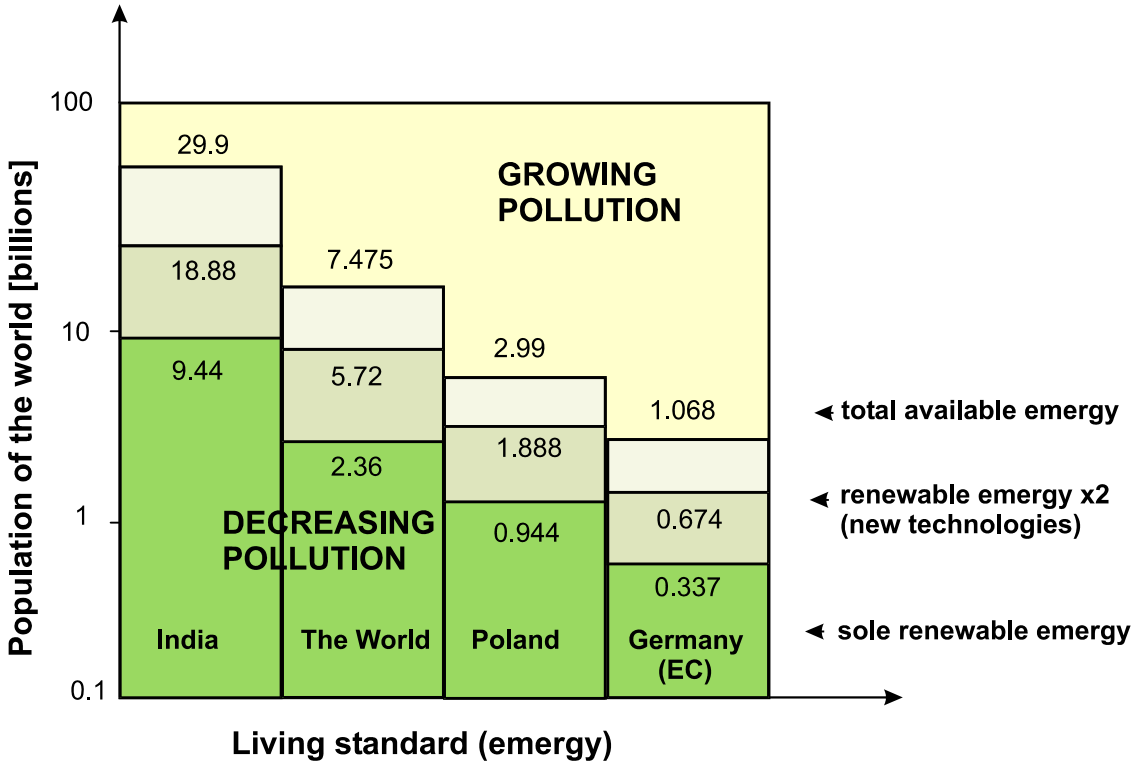

Fig. 3. Estimation of the world population in terms of intervals related to assumed emergetic living standard (Table 3)

The Figure shows two main stepped plots. The lower one corresponds to utilization of only the whole renewable emergy of the world (**OE=9.44 E24 sej/per annum**), while the upper - utilization of all renewable and non-renewable resources with present degree (**NE=20.46 E24 sej/per annum**)., giving total emergy of **CE=29.9 E24 sej/per annum.**

According to the variant shown in the first plot, i.e. utilization of the whole renewable emergy. e.g. in eco-economy [Cempel03] population of the whole world living according to high standard of Western Europe could reach **337 million**. For the Polish standard of 1980s the number could increase to **944 million**, while for the standard of India - about **9.44 billion**. This allows for a

population about 3 times as large as in the present world, living in extreme poverty but free from atmospheric pollution and ensuring presumably quick self-renewal.
According to emergetic variant of the second diagram and utilization of the whole emergy resources (CE) the geobiospheric pollution would obviously increase. Under such circumstances the high West-European standard would be available only to 1068 million people. The Polish standard would create the conditions for 2.99 billion people, while the standard of India - for 29.9 billion. Present population of the world exceeds 6 billions. This enables to imagine the conditions of living in extremely crowded and polluted world.

At present it is already known that physico-chemical pollution results in lowering of immunological barrier in humans. This shall give rise to diseases and epidemics that may reduce the surplus human potential. Anyway, it is not all. There exist also a crowding effect, with its psychic and mental effects on human behaviour. The most important consequences may include increase in aggression toward any potential neighbour, inclusive of children, and drop of creativity and innovative trend in solving the problems.

Rather pessimistic forecast comes from Figure 3. It says that even discovery of new, pure energy sources, e.g. the zero-point energy [Puthoff93] or resonance water diffusion [Genesis02] shall not enable the world population number to increase. So, let us assume that new engineering processes related to the use of renewable energy resources[4] and new, pure energy shall double the use of emergy resources up to **2×OE=18.88 E24 sej/per annum**, which should not result in destabilization (degradation) of the environment, marked in Figure 3 in the form of the middle diagram. An obvious reservation may be here formulated, that consumed non-renewable energy should not exceed the geobiospheric renewability level. Unfortunately, such a fact has already occurred, with the present energy consumption level (the upper curve). Presumably, it is a result of maximal capacity of geobiosphere, taking into account the total effect of physical pollution and the crowding effect.

Of course, there exist considerable doubts related to significance of the data serving for estimation purposes, e.g. the ones provided by [Lewandowski02]. However, this shall not affect the main course of argumentation, i.e. human living with dignity within the framework of renewable concept of geobiosphere utilization as a condition for human survival.

5. Summary and anticipation

Ecological thinking reached such a degree, that many decisions in the West are made basing on emergy estimations [Odum00]. Hence, it is the time for submitting such proposals to geopolitical sphere, in the concern for the future of geobiosphere and further existence of humanity in harmony with their needs. The present work uses the concept of emergy balance in various variants of utilization of its resources, taking into account only available and renewable ones. Appropriate data are considered against four emergetic standards of living on the Earth. The result of such estimation of population number leads to an opinion that extreme data, i.e. 0.3 billion of the highest standard and 30 billion of extreme poverty, should be discarded. Secondly, we should find, as soon as possible, new technologies enabling utilizing of whole available resources of renewable energy, opening the access to pure energy rising no burden to the environment. This would lead to the next problem, consisting in thorough study and consideration of the crowding effect, with a view to limiting potential number of people.

[4] At present we do not use the whole potential of renewable energy in the world. In Poland the ratio of these energies to the total energetic balance barely amounts to 6 percent [Lewandowski02], while by 2010 an increase to 7.5 percent is expected [Strategia01].

5. References

1. Carson R., Silent Spring, Boston, Houghton Mifflin, 1962**.**
2. Lenart W., Skarby tylko dla wybranych, Przegląd, 23,09,2002, s 56 – 57.
3. Odum T. H., Emergy in ecosystem, pp 337 –369, in Ecosystem Theory and Application, ed. By N. Pulmin, Wiley, NY, 446pp.
4. Odum H. T., Environmental Accounting – Emergy and Environmental Decision Making, Wiley&Sons, New York, 1996, 370pp.
5. Odum H. T., Brown M. T., Brandt-Wiliams S., Handbook of Emergy Evaluation, Folio 1 – Introduction and Global Budget, Center for Environmental Policy Environmental Engineering Science, University of Florida, 2000, 17pp, Internet; http:www.enveng.ufl.edu/homepp/brown/syseco/downloads/Folio%201.pdf
6. British Petroleum, Statistical Review of World Energy, 1997, The BP Co, London, 1997, 41pp.
7. Population in Sustainable Development, International Institute for Applied System Analysis, Vien, 2002, 17pp.
8. Genesis World Energy, Internet; **http://genesisworldenergy.org**
9. Cempel C., Ekogospodarka – nowe wyzwanie w kształceniu, badaniach i technologii, NAUKA, 2003, w druku.
10. Puthoff H., Cole D. C., Extracting energy and heat from the vacuum, Physical Review E, Vol 48, No 2, 1993, pp 1562 – 1565.
11. Lewandowski W. M., Proekologiczne źródła energii odnawialnej, WNT, Warszawa, 2002, 308s.
12. Strategia rozwoju energetyki odnawialnej, Ministerstwo Środowiska, Warszawa, 2001.
13. Brown L. R., Eco-Economy – building the economy for the Earth, W W Norton&Co, New York, 2001, 333pp.