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Requirements for a sustainable society.

by
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The UN conference in Rio in 1992, on how to build a sustainable society and the adoption of Agenda 21, indicates that it is now recognised even at a supreme political level, that our society is not sustainable. At the follow-up conference in 1997, it was evident that the criteria for a sustainable society were not yet recognised and specified. The reason is obviously an unawareness about the conflict that exists between the natural laws on one hand, and the political and economic principles, which govern the thinking and acting in our society, on the other, In this context I will call these political and economic principles “the Dream of the Rational Materialistc Paradise”, DRMP.

This conflict between the DRMP and the laws of nature is really very fundamental. According to the first law of thermodynamics, energy is constant and can neither be produced nor consumed, but according to DRMP it is maintained that energy can be produced as well as consumed. According to the second law of thermodynamics, it is impossible to implement any device or process which is able to perform more work or give off more energy than what is supplied to it, but according to DRMP it is maintained that human activities may produce surplus value and create resources which at least correspond to our wages and our consumption of resources?

If the laws of thermodynamics are true, our human activities cannot constitute any exception from these laws and our activities cannot possibly produce more resources than they have to use up in order to produce them, and in such a case the DRMP must be false. If on the other hand, the DRMP is true, it must be possible to produce more resources by way of our human activities such as for instance our technological processes, than these processes have to be use up, and the laws of thermodynamics must then be false. It would for instance be possible to produce more such things as wood or even oil and other fuels from exhausts, smoke and ashes, consuming less fuels than the process delivers.

To my knowledge no such process exists, but still most people seem to believe that DRMP is true. This trust in DRMP is actually so strong, that it is politically very controversial and socially very hazardous and even dangerous to call attention to the conflict between the laws of nature and the DRMP.

Doing so actually “catches the economists and politicians with their parameters down”. To question DRMP is actually equivalent with questioning not only man’s ability to create surplus value by means of his work, but also his technical skill and his intelligence. It further means questioning the technical and economic progress as something that improves the life conditions on earth by creating more resources than it takes to create them.

If the laws of thermodynamics are true, what we usually call technical and economic progress, mean only an increased ability to collect resources from the life supporting system and transforming them and consuming them. By doing so we degrade them to waste.

To pump petroleum out of the ground and to burn it in order to fuel processes is regarded as “energy production” according to DRMP, but according to the laws of thermodynamics it is regarded as consumption of the natural resource petroleum from the life supporting system. According to the same laws of nature we would further be forced to admit that the petroleum is in fact transformed into exhausts and other pollutants when it burns and that energy is released as heat in the process rather than produced. We would further be forced to admit that the petroleum is transformed into exhausts and other exhausts when it burns and that energy is released as heat in the process. We would also be forced to admit that oxygen from the atmosphere is consumed in the combustion process and that the heat, which is released, eventually is radiated out into space. All of this adds up to the life supporting system on earth is losing energy, which once was captured from the sunlight and bound in the photosynthesis and petroleum forming processes. Strictly speaking, the life supporting system loses exergy, since the thermodynamic potential between the petroleum and the oxygen in the atmosphere is levelled. (Compare figure 1 and facts about exergy in appendix 1). This means that the life supporting system approaches thermodynamic equilibrium and that its resources are depleted in proportion to its resources being consumed and broken down to waste and pollutants, which may furthermore contaminate and poison the life supporting system itself.

From the DRMP-perspective, however, extraction and use of petroleum is considered to be profitable and is appreciated as a production of surplus value and creation of resources. The same applies to cutting timber as well as using it as raw materials and fuel. However, according to the laws of thermodynamics this does not produce any surplus value in the life supporting system. On the contrary, this system loses exergy, which was once captured and bound in it during the formation of the biomass.

In order to be able to describe the housekeeping and management of the resources in the life supporting system, that is the real economy, in a way which is in agreement with the natural laws, DRMP must be abandoned and the economic values and assets must be measured and expressed in ways and by methods which are related to the physical reality and in accordance with the laws of nature. One such measure is exergy. It is a quantitative measure of the ability of energy to perform work and bring about alterations of the physical and chemical states of matter. Such changes are in fact characteristic for all transformations. Such as transformations of resources into waste (by which exergy is lost and which may be regarded as costs) as well as all transformations of waste into resources (by which exergy is bound and which may be regarded as revenue).

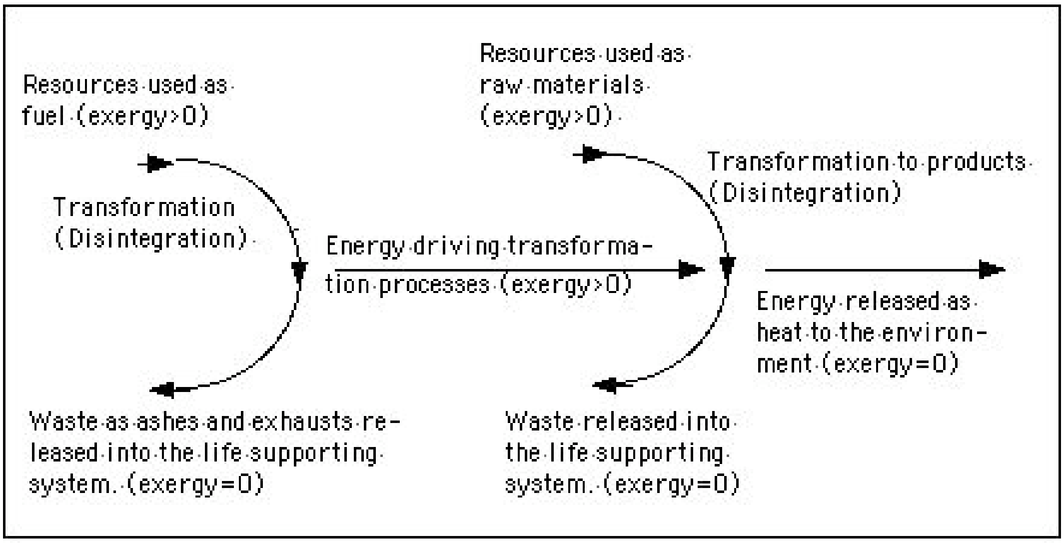

Figure 1

The "production processes" in the society usually break down resources in the form of raw materials. These processes are driven by energy (actually exergy) made available by using additional resources from the life supporting system as fuels converting them to waste products that is exhausts as well.

All transformation processes, including all technical and biological processes, always imply that something is changed, from an initial state to a final state. These initial states and final states always differ from each other with respect to their exergy content. In all transformations and changes more exergy is lost than is captured in accordance with the second law of thermodynamics. Compare facts about exergy in appendix 1 and figures 2 and 3.

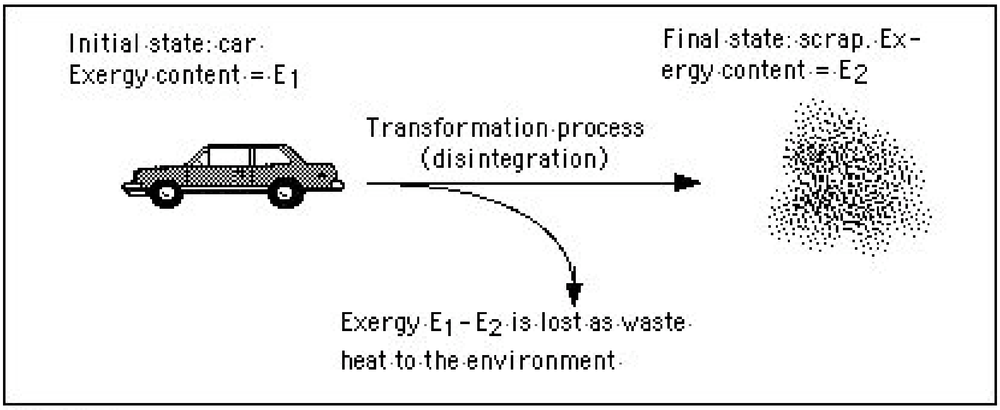

Figure 2.

Conversion of a car to scrap is a spontaneous process, that is a process which proceeds unpremeditated, owing to the fact that the matter in the car has a higher thermodynamic potential and a larger exergy content than the same matter converted to scrap. The transformation process is driven by the difference in exergy content between the car and the scrap and this difference in exergy content is lost as waste heat to the environment, when the car is transformed to scrap.

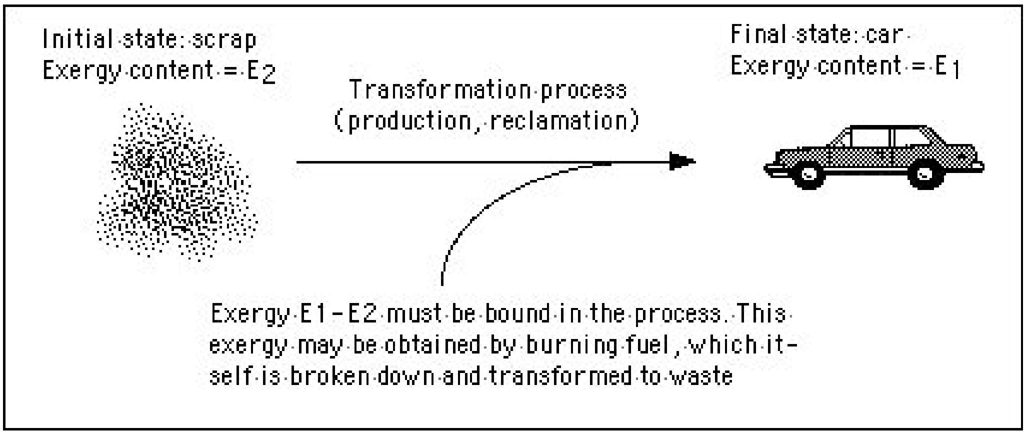

Figure 3

Exergy must always be supplied in order to transform scrap to a car, if the process is going to proceed. This usually means that fuel is transformed into exhausts and other waste products. The amount of exergy which must be supplied to the process is usually many orders of magnitude larger than the amount of exergy, ($E_1 - E_2$) which is bound in the process.(7) The exergy which is not bound in the process, is lost as (waste) heat and dispersed in the environment.

Any transformation from an initial state to a final state, that is all changes taking place in the physical reality, consequently means that energy is converted in such a way that thermodynamic potential is levelled (and entropy is increased). However, energy can neither be formed nor disappear but can only be transformed (the first law of thermodynamics). What is used up, when work is performed, is exergy and exergy is always used up to some extent, when transformation processes take place.

How valuable a resource is in physical terms, is determined by how much exergy it represents (how much power or capacity to change it contains). It is possible to calculate quantitatively how much exergy a certain amount of matter represents as well as how much exergy different forms of energy contain.

When a resource is used up completely, that is when no more use can be obtained from it or no more change can be brought about by it, its thermodynamic potential towards its environment has levelled out completely and all its exergy has been lost. (Its entropy has reached its maximum.) Exergy is usually lost as waste heat, that is as heat, which is emitted into the environment and has such a small temperature difference towards that environment so that no exergy can be obtained from it. Compare facts about exergy in appendix 1.

Thermodynamic requirements for a sustainable life supporting system.

The requirements that must be fulfilled, if the life supporting system on earth including our society is going to be sustainable, are summarised in figure 4.

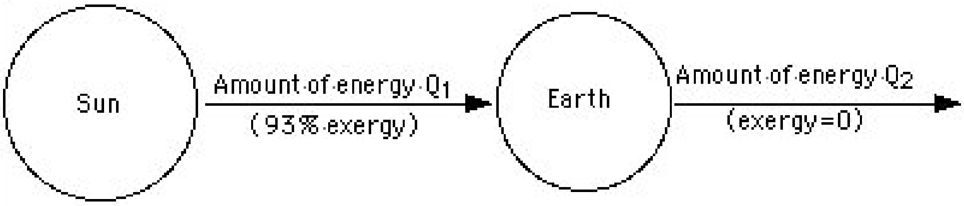

Figure 4.

Earth receives an amount of energy, Q_1, from the sun. This energy has a very large thermodynamic potential (its temperature is about 6000 K) and therefore its exergy content is 93%. From the earth an amount of energy, Q_2, is radiated out into space. Its exergy content is 0 since it is radiated at the prevailing temperature on earth. The difference between Q_1 and Q_2 stays on earth and is bound as exergy in forming resources in the life supporting system.

If Q_1 is larger than Q_2, more exergy is bound in forming resources than what is simultaneously released as heat and lost by braking down resources. A net increase of resources will consequently take place in the life supporting system. The photosynthesis of green plants forming biomass and the further transformation of such material to fossil fuels may serve as an example. In addition the process releases oxygen into the atmosphere and the oxygen content in the atmosphere is increased.

If Q_1 is exactly as large as Q_2 exergy is bound in forming new resources at exactly the same pace as energy is released as heat by braking down resources. If and only if Q_1 is exactly as large as Q_2, the "cycles of nature" are closed.

If Q_1 is smaller than Q_2 less exergy is bound in forming resources than what is simultaneously lost as waste heat by braking down resources.

The conclusion is that the life supporting system on earth (including society) is sustainable if Q_1 is larger or as large as Q_2. If Q_1 is smaller than Q_2, the life supporting system will not be sustainable. (1)

Since we now use more and more fossil fuels, biomass (over and above what is simultaneously reproduced) etc. more exergy is lost as heat from the life supporting system, than what is simultaneously bound into it. More and more of the exergy and consequently also more and more of the resources, which was formed in the life supporting system in the past, are used up and broken down to waste. More energy is accordingly radiated from the earth into space than what the earth is simultaneously receiving from the sun. This means that Q_1 now is considerably smaller than Q_2 and that the life supporting system on earth (including our society) is no longer sustainable. The phenomenon should be called destruction of the environment.

In order to make the life supporting system sustainable and viable, the consumption of exergy that is the breaking down of resources must be drastically reduced. In addition the fixation of exergy from the sunlight into the life supporting system and the renewal of its resources must be increased. This means that a “low energy society” is needed as it was suggested in SOU 1974: 65, Energi 1985 - 2000, appendix 13,(1) However all such recommendations have been rejected by the Swedish government and parliament. The motivation is found in SOU 1974: 64, Energi 1985 - 2000; page. 73 and reads in translation from Swedish:

The debate came also to refer to more general issues like "limits to growth" and the requirements for human survival, but since the energy issue was of immediate importance, the debate was partly centred on the requirement for and the consequences of a low energy society.

In a situation when there is a real and extensive lack of energy and when no alternatives exist, mandatory restrictions regarding the consumption of energy may of course be required, accepted and carried through, even if they would mean very drastic disturbances of our society’s structure and interfere with our way of life. However, in its report, the Energy Forecast Commission was not of the opinion that it was realistic to calculate with a spontaneous development of this kind in the society. Neither was the commission of the opinion that facts on the energy market such as the supply of energy and consideration for the environment as well as considering the consequences, made it necessary, or even possible, to adapt the society to such a development. Therefore the commission did not investigate the possibilities for and the consequences of a low energy alternative, which meant non-growing energy consumption. The commission limited itself to studying only such measures to restrict the consumption of energy, which might be considered to be consistent with the kind of society we already have.

This standpoint is logical for people embracing the DRMP-paradigm, but never the less means conducting a policy for impoverishing the life supporting system by bringing about breaking down of its resources at a faster rate than they are renewed and consequently undermining the living conditions in the life supporting system.

Until at least as much exergy is bound through renewal of resource as is simultaneously released as heat from the life supporting system by breaking down its resources, any statement about environmental control program being successful is misleading. The same is valid for any statement about the society being sustainable. Assertions like “society will be sustainable if we learn how to use the natural resources four times (6), ten times or even twenty five times more effectively, are likewise misleading and an emanation of the DRMP-paradigm The reason is simply that the second law of thermodynamics still implies that it is impossible to implement a device or process which can perform more work or give off more energy than what is supplied to it. Consequently there is good reason to ask what “more effective use of natural resources” really means. If the society as a part of the life supporting system is going to be sustainable, at least as much exergy must be fixed in that life supporting system as it loses through the breaking down of its resources.
Since energy is mainly converted by man in order to exploit natural resources and to carry through processes which transform resources to waste rather than the reverse, the energy turnover in our society may be regarded as being a measure of how over priced our society is for the life supporting system. Further, the increase of the rate of energy turn over may be regarded as a measure of how fast this cost is increasing over time.

In 1954, the turn over of energy in the human society equalled to the combustion of about one billion tons of petroleum.(2) In 1994, it had increased to 7,9 billion tons. (3) During the 40 years between 1954 and 1994, the exergy cost for operating the human society has consequently increased about 8 times, corresponding to an average of 5,3%/year. This has been paid for by the life supporting system mainly as environmental destruction. It is interesting to note, that the exergy cost, which the life supporting system has to pay for the human activities, has increased even faster than the population. This means that it has become more expensive for the life supporting system to keep each one of us going. It also means that the society has retreated more and more from being sustainable.
If data obtained by Hubendick, (4) are used, it is possible to calculate roughly how long it will take to damage the life supporting system with the present policy.

He estimated the stock of living biomass on the continents to be approximately 1650 billion tons, measured as dry stance, (ds) and that this stock was renewed at a rate of about 117 billion tons ds/year. These data are used together with some assumptions in a somewhat simplified but still useful model for calculating how the resources are used and renewed in the life supporting system. The computer program which is used is STELLA® II.2.1, from High Performance Systems, according to figure 5.

The living biomass on the continents, 1650 billion tons ds, is thus assumed to be “resources in the life supporting system”. It is further assumed that the rate of renewal of these resources, 117 billion tons ds/year, corresponds to the amount of resources, which are simultaneously used up for repairing and maintaining the system itself, under which conditions the system will neither expand nor contract. It is further assumed that this rate of resource renewal (117/1650/year) is maintained even when the life support system changes. However, this is admittedly a somewhat questionable assumption.

The human influence on the life supporting system carried into effect on one hand through “Resource increasing technique” and through “Resource-destroying technique” on the other. These uses of technique are in their turn governed by “Economic activity” and it is further assumed that the increase in ”Economic activity” corresponds to an increase of 5,3%/year in the turn over of energy in the society, since the rate of energy turn over has increased this much during the years 1954 to 1994.

If the human activities would have a positive effect on the life supporting system, via “Resource increasing technique”, the life supporting system would be able to fix more exergy from the sunlight and expand. The conditions for life on earth would then grow more favourable. If, on the other hand, the human activities would have a negative effect on the life supporting system, via “Resource destroying technique”, the resources in the life supporting system would be deteriorated and fix less exergy from the sunlight.

According to Hubendick, the biomass in the life supporting system was used up at a rate which was 5 billion tons ds/year larger than the rate of its renewal, (5) hence an initial value of 5 billion tons ds/year has been assigned to “Resource destroying technique” in the model, while “Resource increasing technique” has been assigned an initial value of 0. Compare the equations in figure 6.
The results of the calculations are shown in figure 7. They indicate that any stock of biomass on the continents, older than one year, are used up and broken down approximately by the year 2040.

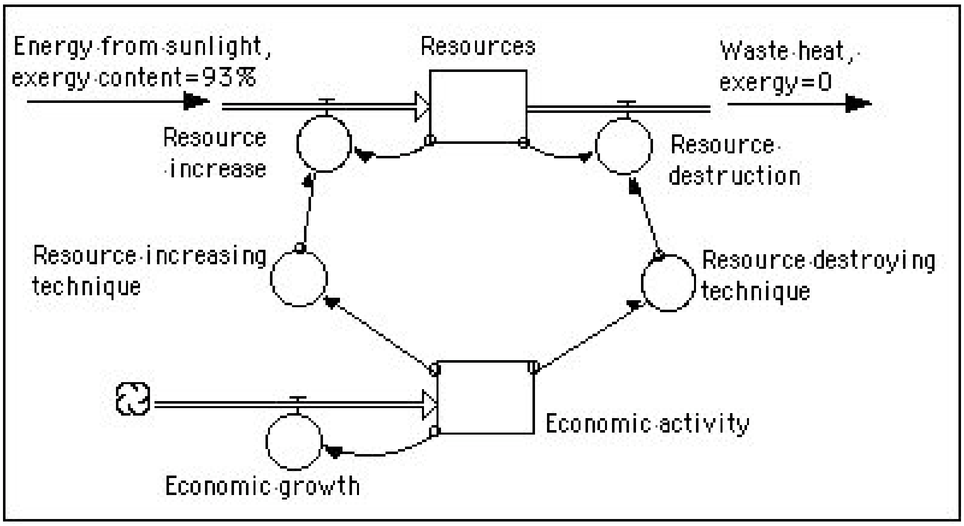

Figure 5
Model for calculating human influence on the ecosystem on the continents.

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Economic_activity(t)= Economic_activity(t - dt)+
+(Economic_growth)*dt
INIT Economic_activity = 1
INFLOWS:
    Economic_growth = Economic_activity*0.053
Resources(t)=Resources(t - dt)+(Resource_increase -
-Resource_destruction)*dt
INIT Resources = 1650
INFLOWS:
    Resource_increase = Resources*117/1650+
    +Resource_increasing_technique
OUTFLOWS:
    Resource_destruction = Resources*117/1650+
    +Resource_destroying_technique
Resource_destroying_technique = Economic_activity*5
Resource_increasing_technique = Economic_activity*0
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Figure 6.

Summary of the equations used for obtaining the results shown in figure 7

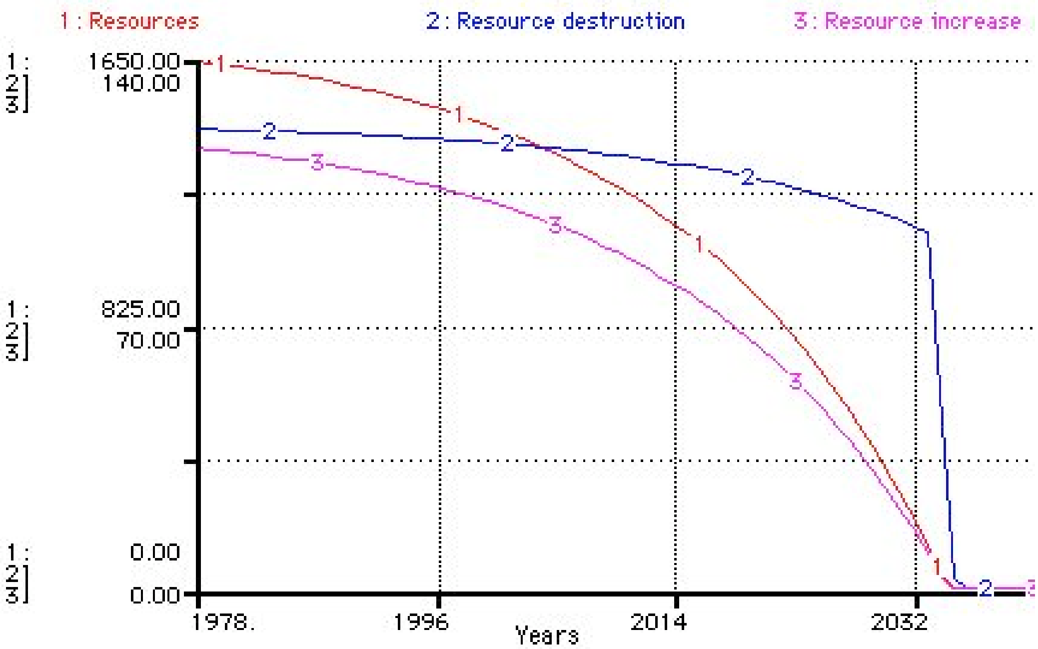

Figure 7.

Calculation results obtained for the model in figure 5 with the data and equations according to figure 6.

However, as long as the laws of thermodynamics are ignored and as long as it is taken for granted that DRMP-paradigm is valid and that man is able to produce surplus value and more resources than he has to consume in order to produce them, he is blind for the difference between the resource increasing and the resource destroying techniques. Undoubtedly however, the physical reality will sooner or later force us to realise that we as well as our activities are no exceptions from the laws of nature. This insight will inevitably call for a reconsideration of the DRMP, which assumes that man and his actions stand outside and above nature, thanks to man's superior intelligence, his rationality and his technical skill.

References:
1. Delin, S .and Ejerhed, A., Sveriges offentliga utredningar, (SOU) 1974: 65, appendix 13., Stockholm, Sweden, 1974
2. Goldschmidt, V. M., Geochemistry, A. Muir ed., Oxford, Clarendon Press, 1954
3. Svenska Dagbladet, Stockholm, 1995.06.30.
4. Hubendick, B. Människoekologi, Gidlunds, Göteborg, Sweden,1985 p. 63,)

5. Hubendick, B., Människoekologi, Gidlunds, Göteborg, Sweden, 1985., p 96-97.
6. von Weizsäcker, E. U., Lovins, A. B.& Lovins, L. H., Factor Four; Doubling Wealth - Halving Resource Use. The new report to the Club Of Rome. Earthscan, London 1997.
7. Delin, S., I den bästa av världar, Brainbooks, Jönköping, Sweden, 1996, p 91-98.

Appendix 1

Facts about exergy

Exergy is a measure of ability to perform work and a universal measure of resources, since it is a measure of change and ability to change for instance of the physical and chemical state of matter. The exergy, E, is defined:

$$E=U-U_{eq}+p_0(V-V_{eq})-T_0(S-S_{eq})-\sum_i \mu_0(n_i-n_{ieq})$$

Where U, V, S and n_i stands for the extensive parameters of the system, (that is internal energy, volume, entropy and number of moles) while p_0, T_0 and μ_0 stand for the intensive parameters of the environment (pressure, temperature and chemical potential) and eq stands for "in thermodynamic equilibrium with the environment".

It is evident from this equation, that the exergy includes extensive as well as intensive parameters, that is amounts of energy and potentials. It is important to note and understand this fact.

For energy, in order to to bring about changes which estrange the state of matter from thermodynamic equilibrium with its environment (which is required in order to create resources out of waste) this energy must have an adequate potential. For example, to change the way in which an electron moves and behaves in an atom and to make it absorb energy, the supplied energy must have an adequate potential, otherwise the electron will not make any potential jump and the internal energy of the atom will not be increased. The chemical state of the atom will consequently remain unchanged and the supplied energy will be transformed into heat and dissipated into the environment at the temperature of that environment. Therefore its exergy content will be 0.