EMERGY SYNTHESIS 5:
Theory and Applications of the Emergy Methodology

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Why Is Emergy So Difficult to Explain to My Environmental Science Friends?

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ABSTRACT

Communication problems concerning the emergy concept, in an environmental science context with no earlier experience from the concept, is described. Problematic areas to communicate are identified as: 1) the size of tidal and deep heat emergy, 2) the sun energy being represented by rainfall or land cycle, 3) the different use of the energy concept, where adding up energies of different kinds is not accepted, and 4) the view on value and connection to economics. Pedagogic experiences are shared regarding: 1) how to communicate the energy hierarchy concept, 2) use of the term biospheric work, 3) the communication benefits of decoupling the hypothesis' of energy hierarchy, maximum empower and pulsing, and 4) communication to economists regarding emergy's relation to economics. Some larger context reasons influencing the communication are also identified as 1) the important paradigm shift in ecology during the 70s, from a holistic ecosystem ecology to a reductionist population and community ecology, and 2) the dualistic view of quantity and quality regarding the four main types of flows existing in systems (energy, mass, money and information), where useful qualitative measures seem to be missing complementing the quantitative measure of information in bits. The main recommendation from this paper is that even more carefulness is spent on explaining that the emergy concept relies on the theory of energy hierarchy, with the implication that the energy concept is used in a slightly, but very important, different way than by most scientists.

INTRODUCTION

In the mid 90's part of a Swedish university department – Division of Ecotechnics – was enlarging its focus from an engineering-oriented interdisciplinary context and a practical holistic "solve-the-problem"-mentality in the field of sustainable development, towards a natural science context and higher demands on explicit academic theoretical foundation. In this search, the emergy concept appeared to be a strong candidate to meet the since long established goal formulation of the department: "ecology, economy and technology in cooperation for a sustainable development". Although the emergy theoretical foundation connects ecology and economy quantitatively and have a practical application branch, ecological engineering, this theory was not able to catch the interest to a larger extent at the department. To the author this was surprising, since no alternative theoretical approach was closer to the goal formulation of the department.

A decade later the author’s view is that this “failure” was due to two main reasons: 1) the emergy concept was difficult to communicate and get acceptance for in a Swedish environmental science context, and 2) lack of recognition of the emergy concept on the national and international arena. It is not unlikely that the second identified reason is due to the same communicating problem mentioned in the first.

This paper is summing up 10 years of the authors experience in communicating the emergy concept in a Swedish environmental science context. The communication can be characterized as follows (in chronological order):
- From the book Environmental accounting (Odum 1996) to the author.
- From the author to the staff of Division of Ecotechnics at Mid Sweden University (where the author was working at that time), during the period 1997 to 2004, given in seminars and journal article study groups.
- From the author to undergrad university students in Environmental Science and Ecotechnology, with one or two lectures given per year, at first in the context of environmental and ecological economics, later in the context of environmental assessment methods.
- From the author to students and others forming an informal evening discussion group, under the heading “ecosophistry” during the period 1998-2005.
- From the emergy group at Center of Sustainable Agriculture in Uppsala to the author, mainly during 1999-2001.

Objectives

- Identify areas that are problematic to communicate;
- Describe the solutions adopted by the author; and
- Suggest other reasons for the communication failure.

The scope of the paper is the context described above, a Swedish university context, mainly of environmental science people, but also others, as high school teachers et cetera.

PROBLEMATIC AREAS TO COMMUNICATE

Size of Tidal and Deep Heat Emergy

In the Swedish context it is taught from small children school that the sun is the driver of the biosphere. Deep heat is not recognized as a driving force in ecology teaching, not even on university level. However, in energy engineering and energy debate rock heat pump energy is used. This heat in the rock – if thought upon at all – is probably often considered as heated indirectly by the sun. Tidal energy is only considered a driving force in coastal ecosystems with obvious tidal changes in water level. To consider deep heat and tidal energy as important driving forces to a land ecosystem or a lake ecosystem, is farfetched for many.

Rain or Land Cycle Representing Sun Energy

In emergy accounting it is normal procedure to use the largest of the local renewable flows to represent the others to avoid double counting. Depending on what ecosystem is evaluated sun, rain, wind or land cycle are the candidates. The double counting exercise can be readily motivated in the classroom, but is very difficult to explain when you are actually in the field with students. In the Swedish scope of this paper rain energy is most common to be the largest input and is chosen to represent the others. It is, however, strange to the students that the sun energy is not accounted for directly when standing in for example a forest ecosystem. It is obvious that it is doing work in the ecosystem on its own as photosynthesis and heating up pale and frozen student spring faces seeking the sun rays. It can be understood that on its way from the sun some of the sun beams has been used to heat up the atmosphere causing wind, and evaporating water causing rain, and that rain and wind are doing work in the forest ecosystem, but there are obviously unused sun beams reaching the system without having been used up producing wind or rain. Even more problematic is to explain in a lake ecosystem what impact local falling rain has on the lake function, and that this function is more important than the incoming sun radiation or surface wind. Of course rain is feeding the lake with
water, but only to a minor extent compared with what is coming in from nearby systems as tributaries to the lake. This inflowing river water is of course treated as import and not as local renewable.

**The Energy Concept**

Most people in the scope of this paper get confused with the way the energy concept is used in emergy accounting. The physicist and engineering habit of conversion of one kind of energy to another kind of energy using heat values has become the totally dominating (“normal”) habit also in environmental science. This view on energy is used in Life Cycle Assessment (LCA), ecological footprints, Factor X-methods, and other, so it is easy to assume that the energy concept is used in the same way also in emergy accounting.

**Value – Connection to Economics**

The “real value”-concept of Odum (1996) meets little opposition from the natural science based part of the scope group of this paper. However, the few environmental scientists with economic background that the author has met have problems accepting the Odum “real value” concept. Some even have problems with the concept of “ecosystems work”, arguing that only humans can do work, not ecosystems.

**PEDAGOGIC EXPERIENCES**

**The Energy Hierarchy**

Explaining the energy hierarchy is, of course, fundamental in explaining the emergy concept. Starting this explanation with the picture of the energy memory concept has its limits from the author’s experience. After some generation shifts in the ecophilosophy group the author discovered that picturing the energy hierarchy with a triangle was the fastest way to introduce the energy hierarchy concept. The emergy measure in seJ can then easily be shown as a measure of the width of the base of the triangle, and transformity a measure of the height in the hierarchy (figure 1). The cognitive picture of the energy hierarchy will then be what it takes to balance a system at a dynamic steady state rather than a path of historical energy memory.

![Figure 1](image)

*Figure 1. a) energy hierarchy, b) energy hierarchy with monetary flow at a certain hierarchical level, c) embedded subsystem.*
The balancing steady state picture also makes it easier to meet the type of critique from e.g. Hornborg (1998) of the old car having a higher emergy value than the new one, since more have been invested in it in the form of maintenance and historical operation. The triangle figures give way to an explanation where emergy represents what is needed to maintain the feature car(-system) including its life cycle, rather than comparing a car early and late in its life cycle.

**Biospheric Work Represented by Rain or Land Energy**

To meet the problematic questions described above of explaining why the direct sun energy reaching the faces of students in a forest ecosystem is represented by the rain falling, the following answer is the best that the author so far has come up with (however, still unsatisfying): The flows of sun, rain, wind and land cycle should not be seen as single flows, but rather representing the total biospheric work allocated to the system window of attention.

**Decoupling of the Hypothesis’ of Energy Hierarchy, Maximum Empower and Pulsing**

According to the author of this paper the “emergy world” relies on three separate hypotheses that are interconnected: energy hierarchy, maximum empower, and pulsing. In the emergy literature the starting point is very often the maximum empower concept, which the author assumes is the chronological way H.T. Odum developed the emergy concept. The pulsing concept is also connected to the maximum empower concept, as probably maximizing empower but has not been proven so yet. The author of this paper has the experience that the communication benefits from the three concepts being decoupled, and the energy hierarchy is presented first. The reason for this is the experience that as soon as the maximum empower concept has been introduced, the discussion almost immediately becomes polarized in for and against the maximum empower concept, spreading mist around the emergy concept. The energy hierarchy concept on the other hand is quite easy to explain and very noncontroversial among most listeners. They can relate easily to the hierarchy concept. The authors own introduction has been taken the same road. To accept the emergy concept I had to reject the maximum empower concept for some years.

**Connection to Economics**

The authors experience is that the Odum (1996) view of monetary flows being results of physical flows, is not accepted nor rejected by most people, whether with scientific background or not. Though dealing with money every day most people have very little theoretical opinion of what money is. People with economic education are generally skeptic to the Odum (1996) view. A better approach towards this group is to introduce the Odum (1984) approach of energy and economy possibly being different tracks, however possible to connect, see figure 2. Money can easily be observed forming hierarchical patterns. Assuming proportionality between the monetary hierarchy and the energy hierarchy of physical flows, is a way to accept the conversion factor between the physical and monetary reality. This alternative explanation gives a possibility to introduce the sc$/S$ conversion factor without challenging the economic science view on money, and still let it be open to accept the energy-economy connection.
Figure 2. The view on money from Odum (1984) where proportionality is assumed between a hierarchy of money and a hierarchy of energy, giving way to use the seJ/$ ratio.

OTHER REASONS FOR COMMUNICATION FAILURE

Paradigm Shift in Ecology during the 70s

A larger scale explanation of communication problems regarding the emergy concept can be found in the emerging set of books, published in recent years, covering the history of ecology. Figure 3 is the authors summary of Donald Worster’s description of ecology (Worster 1994), showing the important paradigm shift occurring in ecology during the 70-ties. After this paradigm shift the reductionist approach of population and community ecology has totally dominated the ecology field. Active ecologists in the older holistic ecosystem ecology paradigm must probably be counted in the unit parts per million during the 80-ties and 90-ties. Environmental scientists working with ecologists are programmed in the reductionist paradigm, often has no knowledge of the recent development in ecosystem ecology, and find new concepts as emergy, ascendancy (Ulanowicz 1997), environs (Patten & Fath (1998), and eco-exergy (Jørgensen 1995,1998) strange to understand.

Measures yet to be Invented

From a system science point of view, there are only four main types of flows in systems, yet known to science. These are flows of energy, material, information and money. Money may be seen as a special flow of information, and this fits well into the main road of quantity-quality thinking that characterized the work of H.T. Odum, and has found a beautiful formulation in Giannantoni (2002). In table 1 the four types of flows are arranged in the frame of quantity-quality.

As mentioned above one of the major problems in communicating the emergy concept is that the average scientist finds the quantitative measure of energy sufficient and think only implicit of quality aspects of energy. When it comes to mass, the opposite is the rule: we are so used to identify different qualities of materials on the everyday scale, and different atoms and molecules on the microscopic scale, that we would never dream of just adding them up easily. The same goes for money. We get amused when the child adds up coins whether they are 10 cents or Euro coins. The information measure, bit, has become familiar to us in the computer age, and many of us easily relates to kilobytes

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<thead>
<tr>
<th>Quantitative</th>
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<td>Energy, J</td>
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<td>Mass, kg</td>
<td>Type of atom- &amp; molecule, kg</td>
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<tr>
<td>Money, numbers</td>
<td>Money, US$</td>
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<td>Information, bit</td>
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and gigabytes (1 byte = 8 bits). However, the situation for the information measure is similar to the energy measure: Our intuitive understanding of information is “useful” information. However, the bit measures only the information content, whether it is useful or not. We can nowadays probably measure how many bits are shouted at night in the rainforest, but we have no measure how much important was said! Intuitively we have the same opinion of energy: that it is something useful that can do work, which is actually exergy according to physicians (H.T. Odum seemed to prefer the expression useful energy rather than exergy, e.g. Odum, 1996).

It is the opinion of the author of this paper, that a measure of qualitative information is lacking. EmBit may be one candidate, which is the bit divided by an appropriate emergy per bit ratio (analogous to the Emdollar concept derived from the dollar divided by the appropriate emergy per dollar ratio). Or the concept of exformation as described in the book “The user illusion: cutting consciousness down to size” (Nørretranders 1991), which features seems much correlated to emergy thinking.
CONCLUSIONS

The main reasons identified why the emergy concept has been so difficult to communicate in a Swedish environmental context are:

- The energy concept is used in slightly another way than most people and scientists are used to.
- The ecology concept is used in another way than many people and scientists are used to.
- The concept of value is used differently than in economic science (very easy, however, to get acceptance from natural scientists regarding this).
- The maximum empower concept is controversial among many and blocks the way to explain the energy hierarchy, which defines the emergy concept.
- The important differences between qualitative and quantitative aspects of the basic types of flows in the biosphere are too often not expressed explicit enough. A qualitative measure of information seems to be needed.

It may be a larger problem than realized that, in the “emergy world” the energy concept is used in a substantially different way than in other methods in the environmental assessment toolbox. But there are no warning signs telling “Warning! You are now entering a zone where traditional addition rules for energy have been changed” (H.T. Odum used to say: “As you know, I don’t like to add up energies of different kinds”, pers. comm. in Copenhagen 2000). The environmental science friend does not realize the sudden change of basic use of the energy concept. In this view the problem is rather psychological than a problem of understanding or different opinions.

The recommendation from this paper is that even more carefulness is spent on explaining that the emergy concept relies on the theory of energy hierarchies, with the implication that energies of different kinds are no longer aloud to add up based on heating values. I.e. that the energy concept is used in a slightly, but very important, different way than most scientists use and have used it.

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