EMERGY and Ecovillage

a Chapter for the Ecological Key of the Ecovillage Design Education

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Introduction

In this article, I wish to introduce students to the important concept of 'EMERGY' as formulated by Howard T. Odum at the University of Florida. EMERGY (spelled with an 'm') can be considered as "energetic memory" or the total amount of energy – both environmental and human – introduced into and utilized by a system over time. If we think of the ecovillage as a whole system, then some of these energy inputs would be sun, wind, rain, money, goods and services from the global economy, knowledge imported from other ecovillages, the genetic inheritance of plants, etc. The question becomes, "How do we possibly compare the value of all these inputs when they use different kinds of measurements?" Odum solved this problem with his EMERGY analysis: EMERGY uses a common denominator, the EMJOULE, which can be translated into a common value, the EMDOLLAR. Says Odum, "By selecting choices that maximize EMERGY production and use, policies and judgments can favor those environmental alternatives that maximize real wealth, the whole economy, and the public benefit" (1996, p.1).[1]

Here is an example of an EMERGY analysis. In this case the system under consideration is a typical salt marsh:

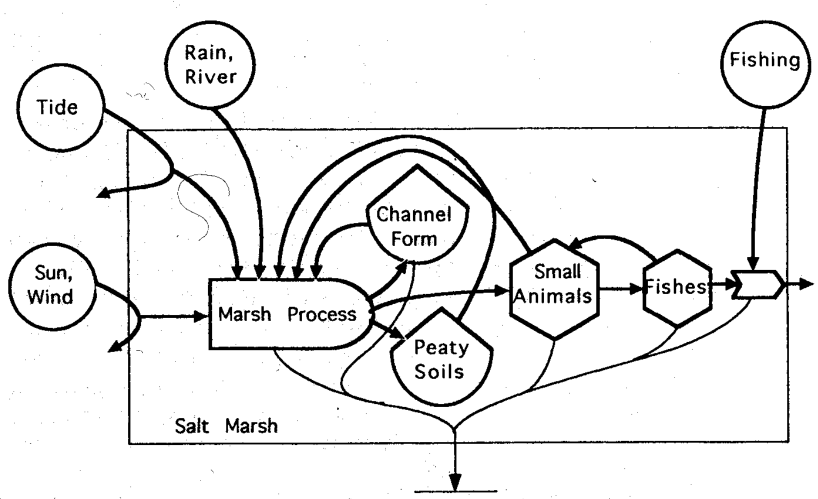


Figure 7.2. Energy systems diagram of a salt marsh aggregated according to the main necessary components and processes as a step in setting up EMERGY evaluation for Table 7.3.

[1] Don't worry if this all sounds way too technical at the moment. My purpose here is to introduce some basic concepts so that later we can apply them to the design of ecovillages.

Since this is a "systems diagram," the first thing we do is create a boundary around the system being observed. Then we note the environmental energy inputs originating from outside the system – 'tide,' 'sun, wind,' and 'rain, river.' These supply energy to the *primary producer* 'marsh processes.' The primary producer stores embodied energy in the *storage tanks* 'channel form' and 'peaty soils.' The primary producer also feeds directly the *consumer* 'small animals' and this consumer in turn feeds a secondary consumer 'fishes.' There is an *interaction gate* where 'fishes' interacts with a further external source 'fishing' to finally produce an energetic output leaving the window. As per the Second Law of Thermodynamics, all components in the system, in the process of doing work, channel degraded energy to a *heat sink*, or ground. This systems overview illustrates clearly the interrelationship between all the parts and between the parts and the whole. It would be possible from here to add specific energetic calculations, in EMJOULES, to each of the components and processes so as to arrive at a total economic value for this salt marsh in EMDOLLARS.

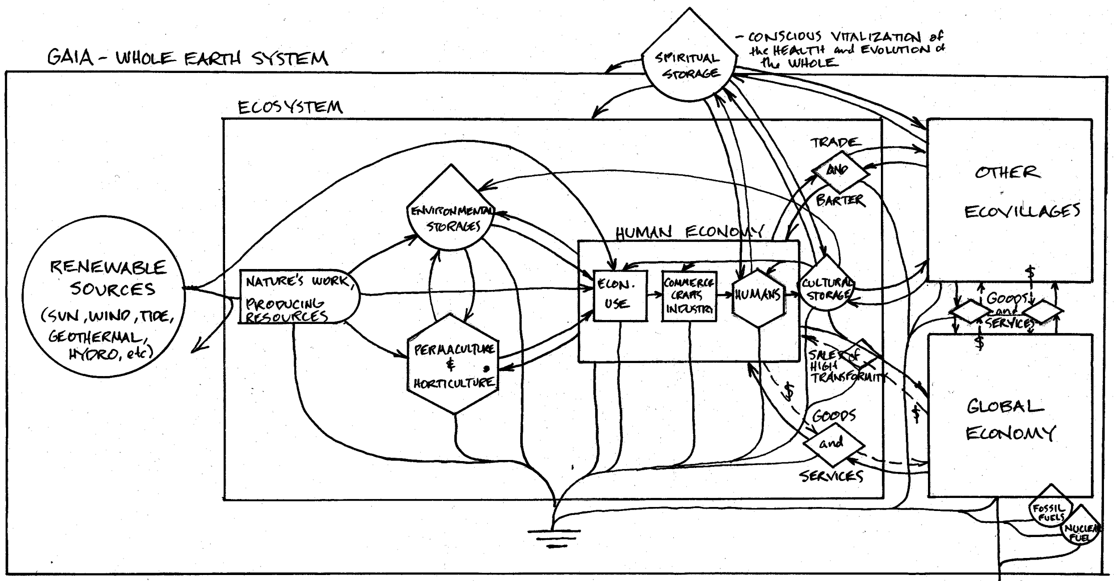
Take special note of the arrows in the systems diagram. These graphically display the *interconnections* being made between components in the system. These arrows represent pathways or *lines of influence*. Of particular importance are the arrows that are moving backwards. These represent *feedback loops*. A feedback loop shows how some of the energy of a component in the system is returned back to its source. In such a situation, the energy that is being returned helps to reinforce or augment the performance of that component. Later we will see how feedback loops can be *designed* into a system to increase total performance – and this is done all the time without people actually thinking of it in these terms.

One more feature of the systems diagram needs to be explained before moving on to playing with these concepts in the design of an ecovillage. In all systems diagrams, high-quality, renewable environmental sources – such as sun, wind, rain, geologic heat, etc. – are depicted on the *left* side of the window, as primary energy inputs. Their gradual, eventual degradation over time in the course of economic work, both environmental and human, is accounted for in the symbols and pathways that move to the *right* of the diagram. In EMERGY terms, this energetic degradation is called *transformity*. All energetic processes on Earth ultimately originate with the initial pure solar input; this is fundamental. The solar input is utilized by bio-geophysical processes at successive steps along the economic pathways until it is eventually consumed; but at each step the initial solar input (available energy) does work of some kind for the system as a whole. Transformity, then, is a measure of the stage of solar degradation, and subsequently, almost paradoxically, energetic investment. "Goods and services that have required the most work to make and have the least energy have the highest transformities" (Odum, p.10). To the left of the systems diagram is high potential energy but low transformity and to the right of the diagram, after successive stages of use, is low consumed energy but high transformity. EMERGY is a calculation of the *total energy* used in the process, and does not degrade or diminish, but accumulates.

Do you see how this idea could be useful when determining the value of energy inputs to an ecovillage? Think about this book you are reading. It embodies *extremely* high transformity but relatively low energy. How many decades of accumulated study and experience did it take for all the contributing authors to finally get their words down on paper? How many meals did the authors consume during all those years? How many individual plants were cultivated and harvested to make those meals? What, then, was the *total solar energy input* that went into producing this book – even before it went into the energy consumption phase of designing, printing, and distributing? While a market economy may assign this book the equivalent value of, say, ten meals and fifty harvested plants, the actual value – what Odum terms *real wealth* – is much, much higher. As another example, what is the real wealth – in terms of total solar energy input – of the genetic inheritance of plants that took *millennia* to adapt to a specific niche? Do you see what I'm getting at? A *sustainable* economy, one that is not subsidized by fossil fuels, will need to start paying attention to these energy transformities. A sustainable ecovillage will prioritize the preservation and enhancement of those energy inputs that benefit the ecovillage over the longest term.

Another way of looking at this is in the language of the energetics of the fundamentals of ecology: "Terrestrial energy in any form ultimately originates from the Sun. Plants, as primary producers, collect this energy and utilize it in their metabolism, photosynthesis, creating sugars and expelling degraded energy. Humans and herbivores then absorb plants for their own metabolism, and in turn expel degraded energy into the environment as waste material that can be utilized by bacteria and other decomposers. The bacteria and decomposers then convert this waste material back into a form that can be utilized by plants. The original pure solar input is eventually lost, however, so the plants need a continual supply of incoming solar energy to keep the whole process alive. This is a simplified version of the primary energy cycle of Life on Earth – it all begins with the Sun. The continual, inevitable degradation of incoming solar energy to less usable forms is termed 'entropy' (heat loss to the environment). A viable economy – which ultimately means the process by which Life sustains *Itself* – will be modeled upon this primary energy cycle. Its goal will be to arrest the flow of entropy and enhance the utility of the solar input at each stage. This is the essence of sustainable settlement economics" (Mare, 1997).

Now that the basic principles have been introduced, it is possible to apply them to the design of ecovillages. Here is an example of a systems diagram for an "idealized" ecovillage, the outcome of a project I undertook in 2002:



IDEALIZED ECOVILLAGE

Here, in true systems fashion, I've chosen to place the window of the 'human economy' of the ecovillage within the window of the 'ecosystem' within which the ecovillage is embedded. This is like saying that the human economy is a *subset* of the ecosystem. The ecosystem, in turn, is placed within the total Gaian system, recognizing that ecosystems don't exist in isolation but are part of larger *supra*-systems. Multiple 'renewable sources' are the energetic inputs for 'Nature's work,' and this primary producer feeds generic 'storages' and 'consumers' of the ecosystem as well as directly the 'human economy' of the ecovillage. The 'human economy' itself interfaces with two external windows: 'other ecovillages' and 'global economy.' Note that all these relationships, as they are depicted, are *reciprocal* energy exchanges, and in the case of the two external economies are characterized by very different qualities of interaction. I've also chosen to add two additional storage tanks: 'spiritual storage' and 'cultural storage,' influences not considered by Odum. 'Cultural storage' is in a position of high transformity, and has feedback loops to all the components of the human economy as well as to the storages of the ecosystem, symbolizing a cultural appreciation for maintaining high stocks of environmental services. While this systems diagram is theoretical, it has the value of displaying in symbolic form a very complex situation. One merely has to meditate upon the various levels of relationship to get a grasp for the essential interconnections in a sustainable ecovillage as a whole. A systems diagram for a "mega-city" would look much different!

Now it might be a good idea to begin wrapping up by encapsulating all these EMERGY concepts into a useful set of design criteria. These criteria will be based upon the proposition that optimal use of available energy is the *essential* characteristic of a sustainable settlement.

The goal here is not to wantonly reduce energy throughput, as if that was some kind of moral imperative, but rather to broaden the concept of energy to its EMERGY counterpart, thus optimizing the use factor of *all* available energy. This will take a lot more thinking than the crude strategy of simply maximizing throughput of crude oil!

Here are the proposed criteria:

1) Diversify and maximize EMERGY *sources.* Since these originate from locally occurring environmental sources, this means a thorough evaluation and inventory of intrinsic environmental energetic inputs, depending in character on the qualities of the particular ecosystem to which the ecovillage is coupled, and including in various proportions: sun, wind, rain, tides, geothermal, hydro, gravity, ecological succession, evaporation, chemical processes, uncaptured flows and surges, temperature differentials, etc. In whatever capacity these sources are available, each needs to be exploited and maximized to its fullest extent. These are 'free' and renewable sources and so amount to a virtually inexhaustible supply of potential energy, limited only by the imagination. Spiritual sources need further contemplation here as energetic inputs. Is conflict a source of energy? Then don't shy away from it, harvest it! What about sexual energy? I believe the matriarchal cultures portrayed by Riane Eisler cultivated this. Love?
2) Diversify and maximize EMERGY *storages.* Applying the concept of transformities, these storages can take on a multitude of forms. For a partial listing: Net Primary Production;[2] biomass fuels such as methane and alcohol; species and thus genetic diversity; productive soils; water storages of all kinds including wetlands, dams, and ponds; tools and tool-making technologies; stored and reusable heat; electric potential stored in batteries; credit unions; useful knowledge and memory in all their forms, including writing, stories, and mythologies; vernacular cultural traditions specific to a place; artwork, including music; seed banks; goodwill and good deeds; etc. In sum, *diversify and maximize the storages of natural, social, economic,* and *spiritual capital.* These storages need to be conserved and multiplied wherever possible entirely within the confines of the ecovillage; they are the real wealth of the community.
3) Given a flow of maximized, diversified EMERGY sources and given a supply of maximized, diversified EMERGY storages, abundant creativity can then be applied to *productively channel and direct the storages into positive reinforcing feedback loops to qualitatively amplify and enhance the productivity of the initial sources*. This takes settlement design to a whole new level; the applications are virtually inexhaustible. A simple example is the use of compost, where crop residues are fed back into the soil from whence they came to enhance agricultural productivity. Another example is when profits from a business are fed back into its infrastructure to make the business more

[2] NPP is the amount of carbon sequestered in an ecosystem from atmospheric carbon dioxide.

profitable. A familiar example from Permaculture demonstrates how *multiple* storages can be employed as positive reinforcing feedback loops: Take a dwelling in a temperate climate that is to be heated by passive solar. The amount of solar insolation falling on the dwelling is fairly constant; yet through good feedback design this steady rate can be amplified. First, situate the dwelling with the long axis running east-west so there is more surface area facing the Sun. Then place a glasshouse on the sun-side to serve as a storage of warm air. Further, place dark-colored barrels full of water in the glasshouse to serve as more heat storage. Place a pond storage in front of the glasshouse to increase solar gain with its reflection. Inside the dwelling, use dark-colored building materials with dense mass as walls in locations where the Sun can shine directly on them. Then, plant a semi-circle or U-shape of tall evergreen trees around the dwelling, open end facing the Sun, to create a favorable microclimate for further trapping and storing heat and deflecting cold polar winds. Each of these design applications uses storages as positive feedback to amplify and multiply the source – the heating effect of the initial solar input. Combined, they can produce a comfortable dwelling in cold weather without the need for heating fuels.

4) Within and among the feedback designs, actively promote complex network configurations for the purpose of creating interconnecting, mutually-beneficial interrelationships. These relationships can support one another in their amplification functions and can serve as a) a string of multipliers when arranged in series, or b) as a multi-pronged power block when constructed in parallel. This principle can be paraphrased by the permaculture aphorism, "Each function is supported by many elements, and each element has many functions." An example of this principle applied to an ecovillage setting would be the cultivation of a wide diversity of companion-planted food crops, many perennial, instead of relying on simple monoculture. Another example would be the rotation of tasks and responsibilities within the ecovillage so that many people can become familiar with them, instead of having individuals always laboring at the same task. This principle can further include (perhaps can even be restated as) the deliberate establishment of multi-purpose, mutually-beneficial, interconnecting communication networks, of all kinds. What happens when we begin maximizing the cross-dimensional interconnections, in parallel and/or series, between available stocks of natural, social, economic, and spiritual capital? This is EMERGY in action; once again, the possibilities are limited only by the imagination.

"Prevailing systems are those whose designs maximize EMPOWER by reinforcing resource intake at the *optimum* efficiency [emphasis added]…This statement includes the maximizing of the resource intake *and* the operation at the optimum efficiency for maximum power…In other words, both *intake* and its best *use* are maximized" (Odum, p.26). Whereas *power* is generally defined as "energy flow per unit time," EMPOWER makes the subtle distinction between *maximizing* sources and *optimizing* usage. "In the competition between sustainable and unsustainable settlements, those that maximize EMPOWER will prevail" (Mare, 2002, p.43). This principle can be applied, for example, to the management of a woodlot adjacent to an ecovillage. Eco-commonsense would say, "Let it grow to its climax stage." An understanding of ecological energetics, however, would insist on keeping the woodlot at 50% NPP – this is the level where EMPOWER is maximized, where the curve begins to move from concave to convex. Can we apply these principles to our daily affairs?

The most important thing to remember about the EMERGY concept is that sustainability can be *quantified*: We can take two settlements and then calculate their ecological energetics using EMERGY principles to discover which one is more sustainable.

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