Energy and Permaculture

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by David Holmgren

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The sustainability debate has shown a deep confusion about the processes and systems which support life and humanity. The lack of conceptual tools to incorporate previously ignored environmental "givens" into calculations used by economists and decision makers is painfully obvious. There are no simple answers to the complex question of costs, benefits and sustainability. However, there is a natural currency we can use to measure our interdependence on our environment and assist us to make sensible decisions about current and future action. That currency is energy.

Energy Laws

Two energy laws governing all natural processes are well understood and have not been challenged by any of the revolutions in scientific thinking during the 20th Century. These laws are called the first and second laws of thermodynamics.

First Law: the law of conservation of energy

Energy is neither created nor destroyed. The energy entering the system must be accounted for either as being stored within the system or as flowing out.

Second Law: the law of degradation of energy

In all processes, some of the energy loses its ability to do work and is degraded in quality. The tendency of potential energy to be used up and degraded is described as entropy which is a measure of disorder. Entropy always increases in real processes.

These laws are taught in every science course, but, in a manner typical of our fragmented society and culture, are completely ignored in the way we conduct our economic life and relationship to the natural world. The laws of thermodynamics are widely viewed as true, but not very useful, theoretical ideas. The second law has always represented a fundamental threat to the modern notion of progress. More traditional and tribal views of the world are in keeping with the second law. For example, the ancient Greek idea of the universe being used up by the passage of time is very pessimistic to the modern mind.

Over the last 20 years, work by ecologists and some economists has attempted to apply the energy laws in more practical ways to understand the global environmental crisis and develop useful conceptual tools for creating a more viable and durable basis for human life[1].

The work of ecologist Howard Odum[2] provided a theoretical framework and conceptual tool which was critical in the development of the permaculture concept. In the 1970s, there was a flurry of research in this field, but it declined along with oil prices in the 1980s. Odum was one of the leading ecologists who developed a systems approach to the study of human/environment interactions. He uses energy as a currency to compare and quantify the whole spectrum of natural and man-made elements and processes.

His ecosystem approach:

- analyzes ecosystem elements and processes in terms of energy flows, storages, transformations, feedbacks and sinks;
- incorporates nonliving and living elements of the natural environment; and
- incorporates human systems and economies as an integral part of the natural world.

Energy Quality and Embodied Energy

The second law of thermodynamics is based on the concept of energy quality. Examination of the natural world, from stellar processes to living systems, shows that differing forms of energy have varying potential to do work or drive processes. Since all forms of energy can be converted into heat, energy can be defined as:

a quantity that flows through all processes measured by the amount of heat it becomes (the calorie is the unit of measure of heat energy).

Dispersed heat is the most dilute form of energy; it is no longer capable of doing work.

All real processes involve a net degradation in energy quality. However, a proportion of the total energy flow can be upgraded into more concentrated forms of energy capable of driving other processes. This creation of order produces remarkable results, most notably life, but includes such nonliving phenomena as rare mineral ores and human-created systems such as the built environment, culture and information. However this order is always at a cost of a net degradation of energy. The whole evolution of Gaia (the living Earth) is a small expression of order arising out of the massive energy degradation of the sun's thermonuclear process.

Figure 1 shows the thermodynamically fixed relationships between four forms of energy ranging from low- to high-quality. These and similar relationships between energies of differing qualities are fundamental to a correct understanding of the energy basis of nature and human existence.

The efficiency of converting sunlight to wood (via the processes of photosynthesis) is 8:8000 or 0.1%. The apparent inefficiency of this process is due to the very low quality of dilute sunlight falling on the Earth's surface. However, 3,800 million years of evolution have optimized this energy-harvesting process, and any technological "improvement" is highly improbable despite frequent claims to the contrary.

Many kinds of high-quality energy are required for complex work. We tend to think of the energy requirements of a process only as fuel, ignoring human work and the contribution of materials. These can often involve more energy than the fuels involved. Figure 2 (next page) shows the energies involved in running a motor car. The fuel is about 60% of the total.

Odum goes on to explain, "the energies involved in the long chain of converging works supporting processes such as educational activities are very large. The total energy required for a product is the embodied energy of that product...The embodied energy of a book is very large compared with the heat energy that would be obtained if the book were burned. For clarity in energy accounting, embodied energy should be expressed as calories of one type of energy such as solar equivalents or coal equivalents."

Many energy studies done by apparently qualified persons and taken seriously by policy makers fail to take account of the simple fact that a calorie of low-quality energy cannot do the same work as a calorie of high-quality energy. Consequently, completely erroneous conclusions are frequently reached. Such problems have afflicted both high- and low-technology proposals. Nuclear power may be the greatest example of an energy "source" which actually uses and/or degrades more humanly usable energy than it produces. Solar, wind and biofuel technologies, while appropriate for the use of already embodied energies, will never sustain high-energy industrial culture without fossil fuel subsidy.

Similarly, computer technologies may be appropriate to make use of manufacturing and networking capacities already in place, but they are in reality very energy-expensive due to their very large embodied energy.

Significance of Odum's Work

Energy Basis for Man and Nature[3] is an accessible text on Odum's work written for high school and undergraduate students with only minimal math and science. It is a very important book which should be read and understood by all permaculturists. Without that understanding it is very easy to be misled into developing and proposing systems of land use, technology and life-styles which will consume rather than produce energy storages useful in providing for current and future human needs.

It provides a way of integrating information about natural systems from local and global scales, technology, environmental impact, and social and economic processes.

The energy accounting and systems diagrams provide a unique tool for understanding and decision making more in tune with the rules of the natural world.

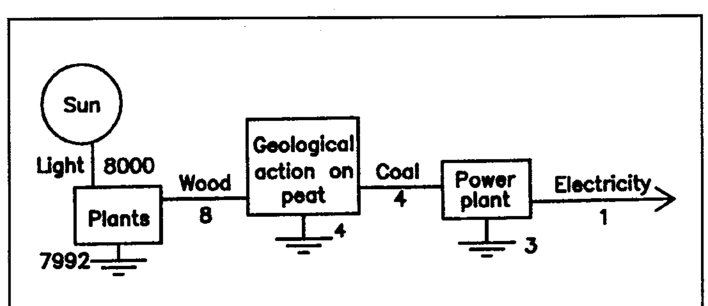

Figure 1. Energy basis for man and nature

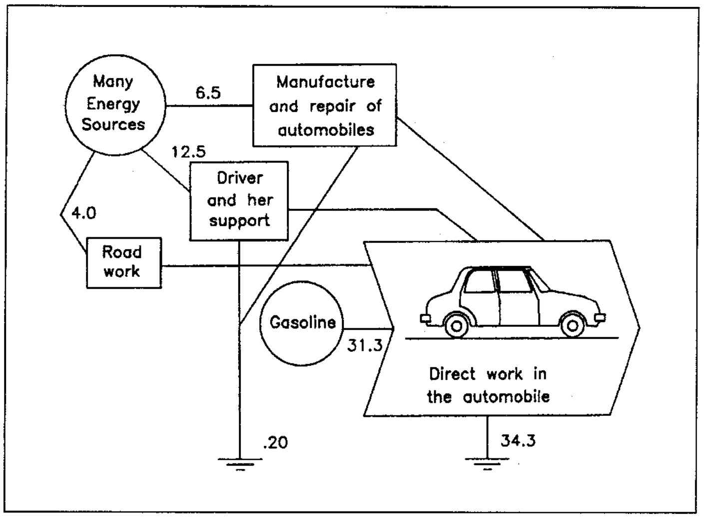

Figure 2. Odum: indirect work outside the automobile

Odum's work shows exactly how and why it is impossible to avoid those rules in any case without the need to resort to moral injunctions. High-energy industrial society is revealed as a quite natural response to fossil fuel abundance but maladapted in every way to a low-energy future.

Agriculture and Forestry

If there is a single most important insight for permaculture from Odum's work it is that solar energy and its derivatives are our only sustainable source of life. Forestry and agriculture are the primary avenues available for harvesting solar energy, and they are potentially self-supporting systems. Technological development will not change this basic fact.

It should be possible to design land-use systems which approach the solar-energy harvesting capacities of natural systems, while providing humanity with its needs. This was the original premise of the permaculture concept. While available solar energy may represent some sort of ultimate limit to productivity, it is other factors which primarily limit it.

Maximum Power Principle

Along with the two established laws of thermodynamics, Odum's work is based on a third principle, the Maximum Power Principle, which explains that the system which receives the most energy and uses it most effectively survives in competition with other systems. Odum states, "those systems that survive in competition among alternative choices are those that develop more power (rate of energy flow) inflow and use it to meet the needs of survival."

They do this by

- developing storages of high-quality energy;
- feeding back work from the storages to increase inflows, recycling materials as needed;
- organizing control mechanisms that keep the system adapted and stable;
- setting up exchanges with other systems to supply special energy needs; and
- contributing useful work to the surrounding environmental systems that helps maintain favorable conditions (*e.g.*, microorganisms' contribution to global climate regulation or mountain forests' contribution to rainfall).

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The Maximum Power Principle is contentious and has led some to criticize Odum's work as "biophysical determinism"[4] with no room for human values. While this systems view is only one way of understanding the world, the last two characteristics of successful natural systems allow plenty of scope for cooperative approaches and higher human values.

The predictive power of Odum's methodology in assessing the chaotic changes in the world over the last 20 years suggests that it is a very useful way of understanding the world. In permaculture, we should use these points as a checklist for sustainable systems.

Mollison

Within the permaculture movement, Odum's work has not been widely recognized (and confused with the work of another American ecologist, Eugene Odum) even though it confirms permaculture's concern with sustainable use of natural systems as the foundation of any permanent culture.

Mollison makes only passing reference to Odum in *Permaculture: A Designers Manual*[5] (page 13) and goes on to suggest, "the concept of entropy does not necessarily apply to living, open earth systems with which we are involved and in which we are immersed." This could be wrongly interpreted as meaning we can design our way out of any problem and that natural systems can sustain the continuous free lunch to which the affluent world has grown accustomed.

In the last few hundred years, we have dug millions of years worth of sunlight (fossil fuels) out of the ground to create a global industrial culture and economy. The most productive sustainable systems imaginable may be able to provide for the needs of five or even 10 billion people. However, they would never sustain large-scale cities, a global economy and western material affluence, even if all the conventional energy-conservation strategies were to be adopted. This is a bitter pill to swallow for Westerners raised on the notion of material progress. This does not mean that the energy-conservation strategies promoted for years by Lovins[6] and other energy optimists, and progressively being adopted, are not incredibly important. In fact, they are essential to make best use of what we have.

The transition from an unsustainable fossil fuel-based economy back to a solar-based (agriculture and forestry) economy will involve the application of the embodied energy that we inherit from industrial culture. This embodied energy is contained within a vast array of things, infrastructure, cultural processes and ideas, mostly inappropriately configured for the "solar" economy. It is the task of our age to take this great wealth, reconfigure and apply it to the development of sustainable systems.

Mollison[5], almost in passing, points to three guidelines we should observe in this task (page 15).

- The systems we construct should last as long as possible and require as little maintenance as possible.

- These systems, fueled by the sun should produce not only for their own needs, but for the needs of the people creating and controlling them. Thus, they are sustainable as they sustain both themselves and those who construct them.
- We can use non-renewable energy to construct these systems providing that in their lifetime, they store or conserve more energy than we use to construct them or to maintain them.

These are very important points, but how should we assess whether we are following them, particularly the thorny question of use of non-renewable energies, raw and embodied? We can apply the following perspectives (derived from Odum) as a primary sustainability test to all land-use systems before considering any more detailed aspects of costs and benefits.

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All terrestrial ecosystems must work to slow the inexorable effects of gravity in progressively degrading the physical and chemical energetic potential expressed in uplifted catchment landscapes.

Eventually everything ends up in the oceans until the next uplift (with the few but important exceptions of onshore winds, migrating fish, and birds). Water and nutrients are the key forms of chemical energetic potential, while the landform itself is the key expression of the physical energy potential. Soil humus and long-lived trees are the key energy storages which terrestrial ecosystems use in the never-ending fight with gravity.

Holmgren's Sustainability Test

Does the system work to catch and store water and nutrients for as long as possible and as high as possible within its catchment landscape?

and

How does it compare with the performance of pristine natural systems as well as wild and naturally regenerated ones (weeds included)?

It is possible for managed productive landscapes to collect and store energy more effectively than pristine systems by the careful use of external, often non-renewable energies.

Figure 3 illustrates useful energy storages in a managed landscape. The use of bulldozers to build well-designed dams capable of lasting hundreds of years in well-managed landscapes is an excellent example of appropriate use of non-renewable energies. Even structures and processes which do not meet this condition (possibly windmills) can be justified because they save the use of greater quantity of non-renewable energies or because they make best use of already embodied energy in existing plant and equipment.

Most of our managed rural landscapes, especially farms, fail miserably on the water and nutrients test. Erosion, salinity, acidification, and stream and groundwater nutrient pollution are some of the symptoms. In addition, use of non-renewable energy as an annual rather than development input is generally very high. (The embodied energy of artificial fertilizers is extremely high).

Wild Productivity

On the other hand, consider the amazing productivity happening right before our eyes from wild, unmanaged systems. In many parts of rural Australia, the land is supporting far more kangaroos than sheep with less damage to the land. These herds could provide a huge meat surplus while maintaining healthy and wild populations.

Forests are even more efficient at catching and storing water and nutrients than sustainable pastoral systems. In the high-rainfall areas of coastal Australia, regrowth forests of native and (in some places exotic) species are developing future timber resources at a greater rate than all the more deliberate efforts at reforestation combined. Simple practices of thinning could greatly improve the future resource value of these forests.

Any systems which can improve soil and water values, require little or no fossil fuel energy to develop and maintain, and provide resource yields largely by the application of human labor and skill, should be seen as our greatest assets.

Urban Landscapes

Urban systems are clearly massive net losses in terms of energy and soil and water values. In addition, the bulk of the physical and information outputs of energy transformation processes in cities is further undermining the social and ecological basis of any sustainable future (*e.g.*, advertising and consumer culture). On the other hand, consider the issue of the vast suburban landscapes. Much has been said about the

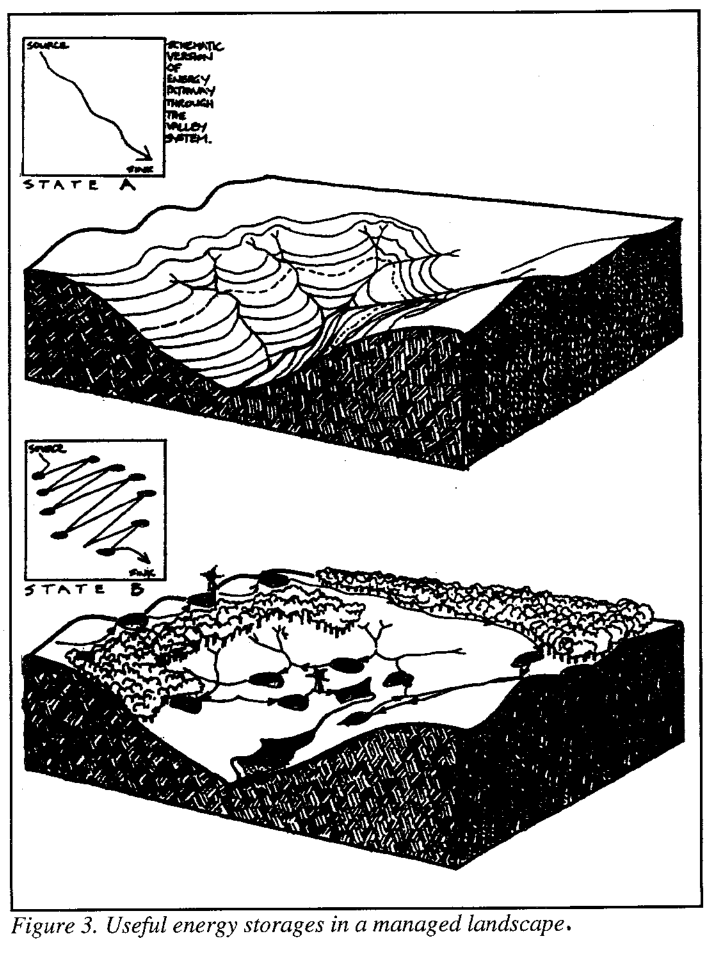

Figure 3. Useful energy storages in a managed landscape.

input requirements of permaculture. This may be true compared to the labor inputs involved in traditional sustainable systems (such as those in China) operating near the limits to human carrying capacity. However, permaculture systems will never be highly productive on very low levels of labor input (such as that required to maintain a well-designed ornamental garden of local native plants). The search for systems which continually reduce human effort is also a recipe for human alienation and the technological fix.

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It remains to be seen whether the significant gains from the application of design skills and genetic resources can continue to build productivity above that made possible by:

- inputs of non-renewable energies during establishment, and
- the use of appropriate traditional (agri)cultural skills.

Odum suggests that all information systems have a high embodied-energy cost. We should assume that (at the material level at least) productivity of sustainable systems will not be vastly different from traditional examples from the past. This may be a very uncomfortable realization for all of us raised on the mythology of material progress and human invincibility.

Energy Scenarios

If net energy availability were to increase (through some optimistic/horrific realization of biotechnological dreams or some other current technological fantasy), then the Maximum Power Principle suggests that nothing would stop humanity from transforming itself beyond recognition. This would be necessary to absorb and use that energy while pushing back the environmental debt yet again, as has been done on a much smaller scale in previous millennia. In such a case, permaculture would be buried in the debris of history, while most existing human culture and values would be swept aside by an avalanche of change.

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Conclusion

The critical issue of the last 20 years of environmentalism has been that of net energy availability to humanity. Permaculture has always been predicated on the assumption that net energy availability is declining after probably reaching a peak sometime in the 1960s. Misjudgment of the timing and precise nature of energy decline by Mollison and myself along with other environmentalists in the 1970s can be attributed to the enormous energy already embodied in industrial systems and culture. This embodied energy has fueled continuing rapid adaptation by industrial society to new emerging conditions. The apparent capacity to do more with less, and other consequences of high embodied energy, have lulled most observers into a belief that humanity is largely independent of energy constraints.

The complexity and severity of environmental and economic crises make it more imperative than ever before that we have a common currency for understanding the changes around us and assessing the available options.

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Footnotes

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