



ENERGY AND EMERGY: REVALUING OUR WORLD

*An earlier version of this article was first published in **Green Connections** (issue 12) in 1997. It shows some evolution in the explanation of Howard Odum's concepts from earlier articles reflecting the deepening of my own understanding. It places the concepts in a historical context linked to permaculture and includes more current references.*



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LETS AS A LESSON IN CURRENCIES

Understandings of concepts as basic as energy and money are bound to be complex, diverse and contradictory. In our society of constant change, we should expect that discussions are usually built on misunderstandings of the definitions implicit in the views of others and even ourselves.

Take money for example, that mechanism which lubricates material exchange and trade, but which has virtually no material basis itself. Money and markets have always been important but at the end of the twentieth century they have been elevated to the status of gods¹. It is very difficult for us to stand back from our everyday involvement with money and see it in a larger context. Generally we resort to old sayings about “money as the root of all evil” or that “money cant buy love”.

The emergence of LETS systems has been a real opportunity for people to realistically consider the role of money by getting their heads around a money system which operates by different rules. However, we are so wedded to money as we know it, that many people don't even recognise LETS as a money system and fail to understand LETS currencies can devalue and crash like other money systems.

Alternative forms of money such as LETS are an important part of the permaculture tool kit for a sustainable society but I want to introduce a much more fundamental concept for comparing and valuing the material world, **emergy** or embodied energy.

UNIVERSAL MEASURES OF VALUE

With the rise of capitalism and the industrial revolution, money and markets began to gain a unprecedented hold on society and everyday life. Many critics emerged, one of the most influential being Karl Marx. Marx concluded that human labour, not capital was the scientifically valid universal measure of value. He saw that it was only when human effort was used to transform resources that real wealth was created. Marxism made it impossible for society to completely ignore the contribution of workers but the passage of history has tended to disprove human labour as the universal measure of value.

Meanwhile the scientific laws governing heat and movement (thermodynamics) were increasingly being seen as applicable to all processes observable in the natural world. The second law of thermodynamics says that *all systems run down to an eventual heat death* ('entropy'). This sobering contradiction of the growth-oriented positivism of modern society has never been regarded as contentious in the scientific community.

The fact that living systems everywhere create order (negative entropy) out of simpler resources, does not contradict the second law. This growth and complexity is always

¹ John Ralston Saul in *The Unconscious Civilisation* Penguin 1997 gives an excellent overview of the historical context for the current ideological obsession with markets.

based on a greater degradation of energy in the wider domain. It depends on where you draw the boundary to your “system” so that even the miraculous growth and complexity of the living earth (Gaia²) is ultimately dependent on the thermonuclear consumption of the Sun (over billions of years).

In all basic physics and engineering courses, students are taught that differing forms of energy can be measured by converting them completely to heat energy and measuring the result in joules or calories. The problem with this conception of energy is that it does not distinguish between differing qualities of energy, which scientists recognise, but largely ignore because of difficulties in measuring these differences.

Energy (measured in heat units) is useful for many comparisons but in the 1930's the technocratic movement advocated the idea of a new currency based on energy. It is not surprising that this was not accepted by economists or society generally. Using energy as a measure of value is only marginally useful in either the natural or human domains since the work of an intelligent human was no more valuable than the equivalent metabolic value of a green leaf photo synthesising, or the value of a book is the same as that of a piece of wood which released the same heat when burnt.

Almost all humanists, social scientists, economists and environmentalists are at one in rejecting the possibility of a universal measure of value.

SYSTEMS ECOLOGY

However, the energetic basis of natural systems laid down by Lotka³ and others did become foundation concepts for the new science of ecology, providing hope that a rational scientific approach to nature could be holistic rather than reductionist. American ecologists Howard T. Odum, and older brother Eugene Odum are two of the pillars of modern ecology but the ongoing development of Howard's work within the field of Systems Ecology over the 70's, 80's and 90's⁴ has been widely ignored or misunderstood by biological scientists let alone economists.

In all natural and human systems enormous flows of low quality energies are necessary to generate small amounts of higher quality energy.

For example, in the simplest aquarium ecosystems 1000 joules of sunlight are needed to produce 1 joule of organic matter. Studies in Swedish spruce forest show that the average production of spruce logs/ha has an energy content of 7.6×10^{10} joules and that the total solar energy flow used to generate this yield is $30,000 \times 10^{10}$ joules.

2 James Lovelock, who coined the term provides an excellent picture of the history and process of the living earth in *The Ages of Gaia* Oxford Uni Press 1988

3 A.J Lotka Contributions to *The Energetics of Evolution* 1922

4 See H.T. Odum *Environmental Accounting* Wiley 1996 for the most current and thorough explanation of the use of Emergy as a comprehensive system of environmental accounting.

The energies required to support human industrial systems were even greater.

Making these calculation requires full evaluation of all the inputs necessary to support any process or system.

Using Odum's terminology the 1 joule of energy in the aquarium organic matter (single celled algae) is said to contain (and be worth) the same as the 1000 joules. The unit solar emjoule measures this embodied energy which is necessary to make any product or service. Thus Swedish spruce logs contain 3846 (i.e. 30,000/7.8) solar emjoules per joule of heat energy released when the wood is burnt.

The fact that ecosystems are partly determined by the invisible non-living external energy sources and high quality feedback of information through metabolic, ecological and organisational process within and between plants and animals is universally accepted by biological scientists but they rarely consider these as more than peripheral to their reductionist focus on the plants and animals.

Systems ecology always starts with a macro or top down view of the larger constraining system before focusing in on the main subject. This approach is regarded by many scientists as unscientific because it does use the reductionist method.

Systems ecology provides another challenge to most scientists by claiming that self organising systems occur at all levels in the material universe and are not restricted to genes, organisms and populations of organisms. As a consequence the systems we observe in nature do not result just from chance interactions between competing lifeforms but a top down self organising system which is driven by the maximum power principle⁵ to evolve to some optimally efficient use of energy and resources. Most scientists refuse to accept this as they see it supporting notions of god. Even the Gaia hypothesis that the whole earth behaves as if it were alive is regarded by many scientists as no more than an interesting myth.

THE OIL CRISIS AND PERMACULTURE

Odum's embodied energy concept remained obscure ecological theory until the first oil crisis in 1973 led to a flurry of new applied research into the energy basis of industrial society. Better ways to measure the real value (as opposed to market value) of fuels and what alternatives existed for industrialised economies were sought.

It was widely recognised that many materials (eg. aluminium) while containing little raw heat energy required enormous amounts of energy to make (eg. electricity). This embodied energy was increasingly seen as a currency which might be useful in considering wider environmental, social and strategic issues which money and markets

5 An emergy restatement of Lotka's *Maximum Power Principle*

failed to consider, let alone measure. A range of methodologies such as Input/Output and Exergy⁶ were proposed for measuring embodied energy. Useful results were produced⁷.

These other methodologies all measure the energy contained in any economic (purchased) inputs to processes but fail to systematically take account of;

- the free services of nature in sun, rain, wind, geological uplift, etc. and/or
- the highly embodied human and other information services which are clearly critical to all human processes.

Odum's work was central to my development of permaculture⁸ with Bill Mollison. It provided a scientifically acceptable way of understanding the power behind human systems as an integral part of nature. This understanding seemed to (a) encompass the truths and values of traditional pre-industrial societies and, (b) provide a framework for designing new systems which could be sustained in an emerging low energy future.

The ongoing development of Odum's methodology includes ways to estimate the value of these services, again based on understanding the principles from natural systems. In 1985, an Australian colleague of Odum's coined the term 'Emergy' in response to the confusion of Odum's embodied energy accounting with other methods⁹.

The failure of price rises in fuels to stall economic growth of industrialised countries led to a decline in interest in embodied energy accounting and an increasing belief that embodied energy concepts were not useful in predicting or making decisions in complex human systems. The Club of Rome warnings of the limits to growth in the early 70's now seemed premature if not wrong. Competition between differing methods led to Odum's more complex and theoretically challenging methods being ignored as others in the field tried to establish environmental economics as a respectable field for research funding in the face of rising economic rationalism.

Today, biological scientists continue to point out the increasing symptoms of unsustainability but seem powerless to provide any clear explanation of how nature will eventually limit economics. In this void, economic rationalism seemed to herald the triumph of markets and money as the measure of everything.

6 Input/Output methods are commonly used to estimate "embodied energy" of building materials while Exergy analysis is used in widely promoted "Natural Step" approach to industrial ecology.

7 For example one study of Gippsland dairy farms showed that use of superphosphate and other fertilisers was the biggest single factor in determining whether the farms represented a net energy gain or loss.

8 Odum *Power Environment and Society*, 1971, is the first reference in *Permaculture One* for good reason.

9 In teaching and writing about Odum's work and its relationship to *Permaculture One* continued to use the old term "embodied energy" (see Energy and Permaculture in *The Permaculture Edge* vol 3 issue 3 Permaculture Nambour 1993) until I came across people in Sweden who were actively using Odum's methodology.

USING EMERGY CONCEPTS

Over the last 20 years, with gradually increasing understanding of the emergy concepts, I have found they have been consistently useful in understanding, and to a degree, in predicting the big picture changes as well as useful in assessing practical alternatives for sustainable development.

The results of emergy accounting are dynamite for current understanding by governments, industry, environmentalists and society generally. Without resorting to conspiracy theories, I am also convinced that the think tanks which inform the multi-national corporations on global investment strategies are using emergy accounting, amongst other tools, to suggest where undervalued resources still exist in the final scramble for the sources of real wealth. It was no surprise to me when the World Bank using some new methodology rated Australia as the richest country in the world on a per capita basis. Emergy accounting showed this in the mid 1980's.

What is so frustrating is the fact that ecologists, environmentalists, policy makers and advisers seem to be unaware of this alternative to the dead hand of market economics.

The consistent results from thousands of emergy accounting studies around the world of systems from insect populations to the earth energy flows, from national parks to farms, from industries to national economies, has now built up an enormous body of knowledge about how our world works from a holistic but scientific perspective.

A FEW NUMBERS

A few examples may illustrate how emergy accounting could reorganise our thinking about what's real and what's important.

Back in 1983, Odum calculated emergy values for primary commodities in world trade¹⁰. When compared to the average solar emjoules per dollar ratio, this showed an advantage to the buyer ranging from 2:1 to 18:1. In other words farmers, producing regions and nations are being badly ripped off by, the mostly rich, consuming nations. Most well informed people now know this, from other evidence, but in this society obsessed with rational method and numbers, these results have the power to change negotiations and relationships if widely known and acknowledged.

At 18:1 wool was the most undervalued commodity assessed and since 1983 prices have collapsed! Innovative new uses for wool such as insulation get some return from Australia's wool stockpile (better than proposals to burn it) but emergy analysis shows that using wool for insulation is a bit like feeding human quality grains to beef cattle - a great deal if you are the buyer, but a rip-off for the seller and poor use of resources for the whole of society.

¹⁰ Odum 1996

Emergy analysis provides a surprising and challenging result for the renewable energy industry. Photovoltaic panels may be the most environmentally sound way to provide a needed commodity called electricity at some sites not connected to the grid, and, banks of panels may be used to complement other primary sources of grid power. But emergy studies of existing solar electric systems¹¹ shows a net loss so large that improvements in technology are unlikely to make the sun a rich source of industrial energy. In other words an industrial society running on solar energy without fossil fuel subsidy is thermodynamically impossible.

EMERGY AND INDIGENOUS BELIEFS

Another example on a different scale.

The total emergy budget of the earth is as follows¹²;

- Input from the sun 3.93×10^{24} solar emjoules/annum
- Input from the deep core heat 4.07×10^{24} solar emjoules/annum
- Input from the moon (tides) 1.5×10^{24} solar emjoules/annum

All other apparent sources are derivative of these.

This dramatically illustrates the beliefs of indigenous people that the natural world is the result of the union of Mother Earth and Father Sky with notable contribution from Sister Moon. The implications of this directly translates into our understandings of the fertility and vitality of parts of the world where the deep core heat of the earth is focused in mountain building and volcanism such as New Zealand, Japan, New Guinea, Italy etc. and the tired and fragile (if gloriously diverse) nature of places like Australia where very little of this energy is present. This distinction between geologically young and old landscapes is a fundamental understanding of land which I teach in our Permaculture Design Courses.

To the above Emergy budget we now need to add that of fossil fuels (stored and upgraded solar energy) which we are mining each year. Recent figures are 9×10^{24} solar emjoules/annum almost doubling the pre industrial budget. So, in emergy terms, humans are extracting and using a store of embodied energy from the earth each year which is almost as big as the whole of nature's annual flow (a large slice of which we have also commandeered). The extraordinary and unprecedented results are all around us and will echo into the next century and beyond.

What is also clear from emergy accounting is that no new sources or stores of energy exist which can sustain current, let alone future growth in human systems. The increasing severe environmental, political and social upheavals of the last thirty years are the symptoms of this underlying reality.

¹¹ Odum 1996

¹² Odum 1996

NEW AGE SPIRITUALITY

Of course, these predictions of decline, if not doom, are generally rejected not only by most economists and technologists but also by many New Age spiritualists as simply the machinations of the material plane. They suggest that, through a change in consciousness, we can access limitless free energy.

I believe that the inevitable decline in material wealth will see a resurgence and eventual dominance of a spiritual view of life but the transition may not be as painless as many gurus and teachers suggest. All the sages of the past have spoken of the harmony of spiritual peace available to all, but history also teaches us that the road is marked by endless false leads and nightmares. I remain very skeptical that, after having gorged ourselves on the body of nature and unleashed the genie of fossil fuels, we (the billion or so middle class people of the earth) can simply shed our unprecedented addictions to the material consumption and step across into harmony and balance without experiencing something of the biblical "valley of death".

PERMACULTURE AS A WAY FORWARD

In this context Permaculture is more than a tool kit for sustainability. It is a stepping stone for the transition from addicted consumerism to responsible production¹³, a half way house between the paralysis of environmentalist gloom about the end of the world and the delusion of spiritual consumerism.

My humanist upbringing makes me cautious about accepting Odum's claim to having found the "holy grail" of numerical valuation within a universally applicable general systems theory. All world views have their limits including rational science but emergy accounting at the very least seems to be a powerful tool for using the best of scientific rationality in the shift to a more holistic world view.

The complexity of emergy accounting makes it difficult for the average person (let alone politician) to fully understand, but the mathematics which underpins emergy accounting is very simple compared with complexity of Relativity or Chaos Theory. Texts have been written for undergraduate university courses¹⁴ but these are now somewhat out of date. The latest book *Environmental Accounting: Emergy and Environmental Decision Making* which is the best source with the most up to date data is available by order from the publisher, John Wiley, for \$175! Not the most accessible information but essential reading for anyone who wants to make headway through the intellectual mire of sustainable development. Ask for it at your library.

¹³ I enlarged on this theme in a paper titled *Permaculture as Development Aid for the North* to the 1994 European Permaculture Conference

¹⁴ H. T. Odum & E. Odum *Energy Basis For Man and Nature* McGraw Hill 1979

For those asking for guidelines on how to act now to help achieve a sustainable future, permaculture principles for building diverse biological support systems are the best we have at present. For down to earth folks, personal, household and community self reliance remains the best security and inheritance we can pass on to our children and grandchildren on the unpredictable slide down the emergy scale.