

## Letters to the Editor

### Emergy definition

1 June 1997

Dear Editor

I write as the author of the nomenclature 'emergy, empower, emdollar, embit, energy memory and the maximum empower principle' in relation to your recent article 'Interface ecosystems with an oil spill in a Venezuelan tropical savannah' (Prado-Jatar and Brown, 1997), in particular, concerning their list of definitions of my nomenclature (pp. 54). Since their definitions depart so dramatically from my own (Scienceman, 1987, 1993), not referenced or quoted by these authors, I find it necessary to make the following comments in reply.

My decision to suggest the nomenclature was not taken lightly, but as a consequence of studying 'Systems Ecology' (Odum, 1983) for about 2 years. With a student background in mathematics, practical and theoretical physics (including Einstein's unified field theory) and research in chemical engineering, I found Odum's masterpiece not only very important, but quite normal, in that combining energies of different forms is theoretically necessary. However, I had never heard of 'embodied energy', and found the use of this phrase by assorted authors using different algebras very confusing, (Odum, 1983, pp. 251–268). I therefore, slowly proposed the new nomenclature to clearly distinguish Odum's concept from all others, particularly from that of Costanza (1980), which was subsequently described by Georgescu-Roegen (1986, pp. 269–272) as 'the greatest algebraic swindle of the century'.

The nomenclature is therefore designed to clarify two issues: first, the combining of energies of different forms and second, embodying or using them up. The first is made very difficult because the National Bureau of Standards (1986) does not include any symbol for 'energy quality', long used by engineers for equating coal and electrical energies by a factor of four. Furthermore, their symbol  $J$ , (referring to the surname of James Joule) is used to describe 'work, heat and energy' alike. But 'work' is a useful energy transformation, and 'energy is a measure of the ability to do work only when comparing quantities of energy of similar forms', (Odum, 1996, pp. 18). The phrase of Prado-Jatar and Brown (1997), that energy is

'sometimes referred to as the ability to do work' is therefore ambiguous and mostly quite wrong.

Prado-Jatar and Brown also define 'energy as a property of all things which can be turned into heat'. But mass can be turned into heat using Einstein's theory of special relativity, ( $E = mc^2$ ), so why bother with units for mass (g), as used in their tables and appendices? I therefore recommend that the symbol 'fJ' be used to refer to any form of energy, which can then be transformed into heat energy 'hJ'. After all, people are constantly referring to solar energy, nuclear energy and information energy, for example, so I now use the phrase 'form energy' to describe the symbol 'fJ'. But, 'energy quality', in the Odum system has been quantified using his 'energy transformation ratio'. I recommended either 'transformations' or 'intensity' instead, combined next day by Odum into 'transformity', a continuous quantitative variable. The word 'transformations' can still be used for discrete steps.

Second, the phrase 'embodied energy' was very ambiguous. For example, one can compare the embodied bullets and jelly-beans inside President Reagan: bullets remain bullets after removal, but jelly-beans quickly disappear into other forms of energy such as chemical or mechanical energies. I therefore contracted the phrase 'embodied energy' into the new word 'emergy', and the phrase 'embodied joule' into 'emjoule', in order to clearly distinguish Odum's concept from all others. I deliberately chose something different but not too different. I recommend symbols 'em.J' to refer to 'embodied joule', and 'emj' to refer to an 'emjoule'. The word 'emjoule' was not a surname, so its symbol does not start with capital 'E'. The 'j' must not be confused with the 'jerk', a unit of time rate of acceleration in mechanical engineering (Den Hartog, 1948, pp. 161). The 'emergy joule' is meaningless!

We must now confront the issue that 'work' is not 'energy' in Odum's lexicon. Odum originally used the phrases 'equivalent energy' and 'equivalent joule', meaning that different forms of energy were said to be equivalent if they were able to do similar quantities of useful work, defined as an energy transformation. He referred each form to a basic, common or source form, such as solar or coal energies and used the symbol 'sej' to mean 'solar equivalent joule', still using it (Odum, 1988) to refer to solar equivalent energy today! But this is far too confusing, so I now prefer to use solar equivalent energy (se.J), embodied solar equivalent energy (em.se.J) and solar energy (semj). Entities can be equivalent without being embodied or used up! Prado-Jatar and Brown continue to use 'sej' however, instead of 'semj', thus continuing the confusion.

Lest anyone complain about endless new terminology, at this stage I should mention that the reverse is really true. I am really trying to clean up long establishment confusion. In particular, the Indo-European word 'wergon', (Ayto, 1990, pp. 201), spawned the words 'work, energy, orgy, organ and liturgy' and Aristotle referred to 'activity' as 'energeia' (en ergon). The phrase 'embodied energy' had become over used, too confused, so I now describe 'emergy' as meaning 'energy memory', meaning a measure of the quantity of original form energy which has been totally used up or transformed into a new form of energy. The original form has disappeared and has become only a memory, a memory stored up in

emergent properties and transformity. Maybe the equation source energy (wergon, activity, work done) ( $q_1$ ) (semj) = transformity (energy quality) (tr)  $\times$  ( $q_2$ ) form energy (fJ) completes clarification of the nomenclature?

The other uses of the phrase 'embodied energy' can also be clarified. As described in detail by Odum (1996, pp. 268), when 'embodied energy' is partitioned between assorted carriers, very different quantities result, none of which conform to the usual laws of either the first or second law of thermodynamics. I now refer to them as mangled-energies to contrast with energy memory, which obeys memory algebra, also not energy conservation algebra. Mangled-energy examples are entombed-energy, entergy, (en.J); mattered-energy, matergy (g.J); monetized-energy, monergy, (\$J) and recycled-energy, recergy (J.J). None of these has any physical significance, although all are mathematically possible. They can be called input-output or hybrid concepts.

I recommend transformity (tr) be written as semj/fJ rather than sej/J as used by Prado-Jatar and Brown.

Prado-Jatar and Brown also list the word 'emdollar', symbol 'EMS', as 'a measure of the money that circulates in an economy as the result of some process'. This use of my word 'emdollar' (Scienceman, 1993), (semd), is actually the upside down application of my original concept. I had in mind the large practical applications of 'emjoules', to mean the quantity of solar energy flowing countercurrent to one US dollar (\$), say in 1980, (or E12 semj). Similarly, I proposed the 'embit' (semb), as the quantity of solar energy required to maintain a unit of genetic information, (or E23 semj) (Odum, 1996, pp. 241). I saw 'emjoule, emdollar and embit' as comparable to length measures 'inch, foot, yard'. Odum and Prado-Jatar and Brown, are now really using 'emdollar' to mean an emergy based international US equivalent Gross National Product dollar (EMS). Bad luck for the 'empound' (EM£), etc!

To summarize my nomenclature, I now never refer to 'emergy analysis'. 'Energy analysis' (Odum, 1983, pp. 251) refers to the scientific activity of reductionism (cutting everything up), whereas 'emergy evaluation' and 'systems energy' refer to putting everything back together again, or synthesis, using all energies expressed together in units of a common form. 'Emergy analysis' is therefore an oxymoron, so I always refer to 'emergy synthesis' instead, (Huang and Odum, 1991; Lan and Odum, 1994).

Similarly, I avoid use of the synonyms, 'kind' and 'type' for 'form' of energies, for they confuse the nomenclature and denigrate the 'form' implications of 'transformity', 'information' and 'conformation'. Comparisons can be easily made with historical analogues, such as Marx's use of 'embodied abstract labour time' (hours of human work in a capitalist system), and Freud's use of 'disembodied libido' (body energies combined) to produce neurotic systems and civilizations, but that must be for future papers.

Finally, although not mentioned in the Prado-Jatar and Brown list, I wish to mention 'empower'. The concept power in the SI is defined as the watt, or time rate of change of energy, joules per second, symbol W(J/s) and dimensions  $ml^2 t^{-3}$ . Similarly, I have defined the word 'empower', with unit 'emwatt', to mean the time

rate of change of emergy, e.g. symbol  $\text{semj/s}$ . Except to say that 'transformity is not dimensionless' (Odum, 1988, pp. 1135) no one, to my knowledge, has displayed any new dimensions of emergy or transformity in relation to the SI units, except my own provisional paper (Scienceman, 1993) which inserted a 'p' (meaning 'past') in the dimensions of relevant quantities. It is therefore appropriate for 'the maximum power principle' (Odum, 1983, pp. 6; Hall, 1995, pp. 311-330) to be renamed 'the maximum empower principle, a hypothesis which explains much of science' (Odum, 1995, pp. 521), but not 'the maximum emergy principle' (Brown and Herendeen, 1996, pp. 221).

David M. Scienceman  
c/o Australian Rural Group, Ltd.  
PO Box 307, Bathurst, NSW, 2795,  
Australia  
1 June 1997

## References

- Ayto, J., 1990. Dictionary of Word Origins. Bloomsbury, London.
- Brown, M.T., Herendeen, R.A., 1996. Embodied energy analysis and EMERGY analysis: A comparative view. *Ecol. Econ.* 19, 219-235.
- Costanza, R., 1980. Embodied energy and economic evaluation. *Science* 210, 1219-1224.
- Den Hartog, J.P., 1948. *Mechanics*. McGraw-Hill, New York.
- Georgescu-Roegen, N., 1986. Man and production. In: Baranzini, M., Scazzieri, R. (Eds.), *Structures of Enquiry and Economic Theory*. Blackwell, Oxford.
- Hall, C.A.S. (Ed.), 1995. *Maximum Power: The Ideas and Applications of H.T. Odum*. University Press of Colorado, Niwat, USA.
- Huang, S.L., Odum, H.T., 1991. Ecology and economy: EMERGY synthesis and public policy in Taiwan. *J. Environ. Manage.* 32, 313-333.
- Lan, S., Odum, H.T., 1994. EMERGY synthesis of the environmental resource basis and economy in China. *Ecol. Sci.* 20, 63-74.
- National Bureau of Standards, 1986. In: Goldman, D.T., Bell, R.J. (Eds.), *The International System of Units*. US Department of Commerce, Washington DC.
- Prado-Jatar, M.A., Brown, M.T., 1997. Interface ecosystems with an oil spill in a Venezuelan tropical savannah. *Ecol. Eng.* 8, 49-78.
- Odum, H.T., 1983. *Systems Ecology*. Wiley, New York, (republished, *Ecological and General Systems*. University Press of Colorado, Niwat, and revised for emergy).
- Odum, H.T., 1988. Self organization, transformity, and information. *Science* 242, 1132-1139.
- Odum, H.T., 1995. Energy systems concepts and self-organisation: A rebuttal. *Oecologia* 104, 518-522.
- Odum, H.T., 1996. *Environmental Accounting: EMERGY and Environmental Decision Making*. Wiley, New York.
- Scienceman, D.M., 1987. Energy and emergy. In: Pillet, G., Murota, T. (Eds.), *Environmental Economics*. Roland Leimgruber, Geneva, Switzerland, pp. 257-276.
- Scienceman, D.M., 1993. The system of emergy units. In: Packham, R. (Ed.), *Proc. of the ISSS meeting in Western Sydney, Australia, International Society for the Systems Sciences, Louisville, KY*. pp. 214-223.



## Letter to the Editor

The Authors respond  
1 August 1997

Dear Editor

This letter is in response to the letter by David Scienceman (Scienceman (1997)) regarding emergy terminology, prompted by our recent contribution to *Ecological Engineering* (Prado-Jatar and Brown, 1997). In our manuscript, which dealt with emergy evaluation of a Venezuelan oil spill, we provided several definitions such as energy, emergy, transformity, etc. Dr Scienceman appears to have taken exception to these definitions. He is concerned that we have defined several things and used terms differently than he prefers.

Dr Scienceman's contributions during his stay with H.T. Odum in Florida as visiting scholar from Australia were important, as were the contributions made by many during those years. Development of concepts, terminology and methodologies during that time was a team effort of faculty, visiting scholars, students and friends led by H.T. Odum. It was a most stimulating period when the group in Gainesville, meeting regularly in our seminars and courses, made significant progress in advancing the concepts of emergy and conducting numerous studies of processes, regions and nations that supported our theoretical work. Many scientific reports, manuscripts, theses and dissertations were published during those years, often with differing terminology, as our use of terms and nomenclature coalesced. It was during this period that Jean Michael Cousteau and his late father Jacques Yves Cousteau provided research funds and logistical support to our group. Through their support we were able to evaluate many economies and production processes around the globe, helping to advance the concepts and principles of emergy evaluation. The Cousteau's Vice President for Science and Education, Dr Richard Murphy, was instrumental in getting our group involved with the Cousteau Society and contributed to several of our studies.

Dr Scienceman brings up several points regarding our definitions. First he takes issue with our definition of energy, suggesting that it is ambiguous. I agree. In light of what we understand about energy quality and our work using emergy, the term

energy and its definitions are very ambiguous, but never-the-less they still exist. Second, he is concerned that we use the phrase 'equivalent solar energy' when describing solar energy, fearing, I believe, that we will then be tempted to suggest that 'sej' means solar equivalent joule. However, we are well aware that 'sej' is the unit abbreviation for solar emjoule. He now prefers 'semj', but we do not see the need to change the nomenclature.

Scienceman also is concerned with our use of the term 'emdollar'. He believes that the emdollar should be a fixed standard reference quantity, relative to the US dollar. For several years now, in published literature, scientific reports, theses and dissertations, we have used the term to mean the amount of economic activity that is related to a given flow of energy. The quantity of emdollars associated with an energy flow is obtained by first calculating a ratio of the total energy use in an economy,  $U$ , to gross domestic product,  $GDP$ ... ( $U/GDP$ ; whose units are  $sej/\$$ ). Energy flows can then be divided by this ratio to express them in emdollars. A unit other than dollars is necessary to describe this measure, since it in no way resembles price, that which dollars usually measure. We continue to use the emdollar as the unit measure for the amount of economic activity associated with (flowing counter-current to) a given amount of energy.

Numerous proposals for new symbols are contained in Dr Scienceman's letter including: 'fJ' for form energy, 'hJ' for heat energy, 'se.J' for solar equivalent energy, 'em.se.J' for embodied solar equivalent energy, etc. Some of these we find useful for concepts we have been wrestling with for a decade or more (i.e. form energy = fJ), but believe that their use will add confusion rather than clarity. The proliferation of symbols does not serve well to synthesize, but requires us to travel farther and farther down the road of reductionism splitting concepts into an ever increasing speciation of terms and symbols.

In all, David Scienceman made important contributions to our work in careful and thoughtful propositions of words and nomenclature to describe concepts and theories that have been in the making for decades. We acknowledge his contributions yet feel that they do not constitute ownership.

Mark T. Brown

Department of Environmental Engineering Sciences  
University of Florida  
Gainesville, FL 32611  
USA

#### References

- Prado-Jatar, M.A., Brown, M.T., 1997. Interface ecosystems with an oil-spill in a Venezuelan tropical Savannah. *Ecol. Eng.* 8, 49-78.  
Scienceman, D., 1997. Energy definition. *Ecol. Eng.* 9, 209-212.



## Letter to the Editor

### Another reply

15 July 1997

Dear Editor

You asked for comment on David Scienceman's letter regarding Energy terminology. As a visiting scholar from Australia to the Department of Environmental Engineering Sciences at the University of Florida, Dr Scienceman contributed in major ways to the concepts and application of energy evaluation off and on over a 10 year period. I prefer 'energy evaluation', since the process is both analysis and synthesis at the same time.

The concepts were published earlier under different names. Appendix E (pp. 316-317) in *Environmental Accounting* (Odum, 1996) provides dates of use and numerical values for each span of years starting in 1967.

It was a team agreement in 1983 that new terminology was necessary for the rigor of the energy hierarchy concepts to be clear. Elisabeth C. Odum suggested embergy as short for embodied energy. As a library scholar without equal, David researched the basis for scientific nomenclature and linguistic roots. Energy, transformity and empower were used by us thereafter in many theses, dissertations, papers and books. One editor found energy to be confusingly close to energy in spelling and made me change it to enenergy for that paper. E. Tiezzi recognized the importance of an energy-related entropy concept: emtropy.

Since 1983, all of us used sej as the abbreviation for solar emjoules. However, I see nothing wrong with semj as its abbreviation except for its length. Embit seems confusing (possibly implying a product) when what is meant is energy per bit. Transformity is the energy per joule of a particular form of energy (Scienceman's fj). But as an abbreviation in a numerical table  $sej/fj$  is not helpful because the f for form doesn't say which form of energy. To be complete one has to write  $sej/coal$  joule or  $sej/snake$  movement joule. A recent paper was entitled "The ratio of energy to exergy". Where only one kind of exergy is in the denominator that ratio is transformity. Adding different kinds of available energy as exergy ignores the hierarchical differences in kinds of energy (types, forms). I refer you to my book, *Environmental Accounting* (Odum, 1996).

Scienceman's letter is needed to show how these definitions follow the tradition of care with units and dimensions from physics and engineering. On the other hand, he could be more charitable by not criticizing verbal explanations intended for other kinds of audiences, so long as the concepts are correctly used. Scienceman also uses concepts qualitatively for some purposes such as his delightful energy systems representation of the plot in Wagnerian Opera. With his help we assembled a booklet manuscript entitled 'The Writings of David Scienceman' and hope that he will make final corrections and authorize its publication.

*Howard T. Odum*

Department of Environmental Engineering Sciences  
University of Florida  
Gainesville, FL 32611  
USA

#### References

Odum, H.T., 1996. Environmental Accounting, EMERGY and Decision Making. Wiley, NY, 370 pp.