Errata and Comments
Updated December 17, 2008

Note: Additional comments or corrections can be sent to campbell.dan@epa.gov

Table 9 and the Definition and Symbols for Aggregated State Flows

The symbols used in Table 9 were modeled on an early state analysis of Texas (Odum et al. 1987, p. 124). In later studies (Odum 1996, p. 196), the symbol N_1 stands for concentrated use rather than mineral production. Concentrated use includes all fuels and minerals used in the state as well as electricity generated form nuclear and hydroelectric sources. Mineral production N_1 in this report includes the minerals (coal, clay, oil, etc) produced in the state without adding imports, similar to the Texas report. In West Virginia, hydroelectric power is very small, and thus it was not included in N_1. A number that is practically equivalent to concentrated use, N_1, in Odum (1996) is F_1, minerals and fuels used in the state.

Some other flows are defined differently in these two reports. For example, the total emergy inflow, N, in the West Virginia report is the inflow from outside the state, whereas in Odum (1996) total emergy inflow, N, includes fuel and mineral use from within the United States. I believe that equivalent numbers are used in the calculation methods for subsequent indices; however, the symbols in an expression may be different, for example in the expression for total emergy use, U, Odum uses N_1 and we use F_1 but these are essentially the same number. The quantities that are defined differently should be adjusted to be equivalent before use in an index for comparison among systems. The indicators that are defined differently should be renamed to avoid confusion in the future. For example, the West Virginia indicator total emergy inflows, N, could be renamed total emergy inflows from outside the state compared to Odum (1996) where total emergy inflows, N, meant the total emergy inflow to the state system including flows from within the state. Both ideas are legitimate and may be useful, but we failed to catch this distinction before publication.

In addition for the standard format, the symbols, PI_i and PE_i should be P_2I_i and P_1E_i, respectively, where P_2 stands for the emergy to dollar ratio for the larger system (the nation for a state within the United States) and P_1 stands for the emergy to dollar ratio of the system under analysis (in this case the State of West Virginia). In Table 9 of this report dollars spent by tourist and federal outlays in West Virginia generate emergy flow at the West Virginia emergy to dollar ratio, however the emergy value of West Virginia services in exports are figured at the same average rate as the rest of the country. We chose to do this because West Virginia services do not appear to embody any premium in emergy value over similar services provided elsewhere in the nation. Such decisions need to be made on a case by case basis after considering conditions in the system under analysis, until more research on the emergy value of human services has been done. For example, the usual assumption for estimating the emergy of services would be entirely appropriate when comparing trade between the US and the world or between a developed and a developing country. Table 9 with the P_1 and P_2 symbols is attached

There may be additional errors in this report and I will add material to this page as they are recognized or reported.

Table 9

Summary of Flows for West Virginia in 1997.

Note	Letter in Fig. 2	Item	Emergy E+20 sej	1997 Dollars E+9 $/y	1997 Emdollars E+9 Em$/y
54	R_R	Renewable emergy received	105		8.75
54	R_A	Renewable emergy absorbed	66		5.50
55	N	Nonrenewable source flows	2059		171.58
56	N_0	Dispersed Rural Source	3		0.25
57	N_1	Mineral Production (fuels, etc.)	2056		171.33
58	N_2	Fuels Exported without Use	1500		125.00
59	F	Imported Minerals (fuels, etc.)	265		22.08
60	F_1	Minerals Used ($F+N_1-N_2$)	821		68.42
61	F_2	In State Minerals Used (N_1-N_2)	556		46.33
62	G	Imported Goods (materials)	948		79.00
63	I	Dollars Paid for All Imports		31.13	
64	I_1	Dollars Paid for Service in Fuels		1.72	
65	I_2	Dollars Paid for Service in Goods		23.24	
66	I_3	Dollars Paid for Services		6.17	
67	I_4	Federal Transfer Payments		10.40	
68	P_1I	Imported Services, Total	375		31.25
69	P_1I_1	Imported Services in Fuels	21		1.72
70	P_1I_2	Imported Services in Goods	280		23.33
71	P_1I_3	Imported Services	74		6.20
72	P_2I_4	Emergy Purchased by Federal $	601		50.08
73	B	Exported Products (goods + elec.)	1176		98.00
74	E	Dollars Paid for All Exports		31.08	
75	E_1	Dollars Paid for Fuel Exported		3.92	
76	E_2	Dollars Paid for Exported Goods		26.60	
77	E_3	Dollars Paid for Exported Services		0.58	
78	E_4	Dollars Spent by Tourist		4.00	
79	E_5	Federal Taxes Paid		6.85	
80	P_1E	Exported Services, Total	373		31.08
81	P_1E_1	Exported Services in Fuels	47		3.92
82	P_1E_2	Exported Services in Goods	319		26.58
83	P_1E_3	Exported Services	7		0.58
84	P_2E_4	Emergy Purchased by Tourists	231		19.27
85	P_2E_5	Emergy Purchases Forgone	396		33.00
86	X	Gross State Product		38.3	
	P_1	Emergy to dollar ratio for US	1.20 E12 sej/$		
	P_2	Emergy to dollar ratio for WV	5.78 E12 sej/$		

Errata 2

Additional corrections reported June 28, 2005.

(1) Updated URL for global heat flow.

http://www.heatflow.und.edu

(2) On page C-15, the Gibbs free energy of iron ore relative to its weathered state in the environment was reported as 16.2 J/g. This number should be 14.2 J/g as given in Odum (1996).

Errata 3

Corrections reported August 3, 2005.

In Appendix E, Table 6 the column headed "1997 Dollars" should be E9 $/y and the column headed "2000 Emdollars" should be labeled E9 Em$/y. Note also that flows per year have been variously indicated as /y, /yr, and y^{-1}. (These corrections were reported by Vito Comar, 6/20/2005).

Erratum 4 (posted 12/17/08)

Ma Yanfei reports from China that the value for erosion from cultivated cropland cited on Page C-14 is incorrect the correct value should be 2760168.37 tons/y. The value of the energy lost in erosion from cultivated lands is correct, because the incorrect value is a typographical error and the actual calculation was done on a spreadsheet.

Comment on additional state studies now in progress.

The Commodity flow survey is calculated every 5 years, thus the data that was derived from this source are the same for both 1997 (a survey year) and 2000 (an interim year).

We have begun to calculate emergy indices for Minnesota, Virginia, and Maryland three of the eight states that were analyzed by this method. These numbers show that some of the observations made from comparison of West Virginia indices to similar indices from older studies are not valid. For example, the emergy use per person is similar in both Minnesota and West Virginia as is the electricity use per person. However, West Virginia still produces considerably more electricity per person than does Minnesota. This quality of life indicator is different among countries in various states of development (Odum and Odum 2001) but may be fairly similar between areas of a country in the same overall state of development. We will continue to report observations and changes as analyses are completed for the additional seven states (MN, VA, MD, DE, PA, NJ, and IL.

Errata 4 and Answers to David Scienceman's Comments
Posted September 14, 2004

(3) In Figure 2, R_A should be 66 not 68.
(4) On page 4-1, 2nd column, 3rd sentence, the word 'fluxes' should be flows.
(5) In the explanation of emergy, the derivation of the word 'emergy' as an acronym 'em" from the concept of "energy memory" should have been explained (Scienceman 1987).

Scienceman, D.M. 1987. Energy and Emergy. Pp 257-276 in Environmental Economics. G. Pillet and T.. Murota (eds.) Roland Leimgrubber, Geneva. 308 pp.

Response to David Scienceman's Comments on the West Virginia Report EPA /600/R-05/006

Dr. Scienceman's questions and comments are presented in a question and answer format. First, D. Scienceman's comment is given and then our answer to that comment follows. Dr. Scienceman makes many good points and the reader's understanding of this subject will be increased by a careful reading of his comments and our answers.

Note: David Scienceman's comments are not presented in their entirety. Only those comments and questions that could be answered are included.

D. Scienceman:. I can't comment on USA statistics.

1. All data sources are given. Those from U.S. government web sites can be readily obtained. Many of these sites include material on the statistical reliability of the data.

D. Scienceman : I was very pleased to see I_1,. I_2, I_1, and E_1, E_2, E_3, have been clearly displayed with calculations

2. We intended to use standard symbols for the aggregated state diagram in this document, but see the http://www.epa.gov/aed/research/desupp3.html for differences from Odum (1996).

D. Scienceman : I was very interested in your addition of water calculations (Romitelli 1997) in item 54, which contrasts with Odum (1996, page 186-187)which only seems to use rain.

3. The treatment of water emergy in this paper is consistent with the total body of Odum's work on this subject. I have added a refinement in explicitly distinguishing the emergy received by the system from the emergy absorbed by the system. It is, of course, the emergy absorbed by the system that is responsible for creating order and organization there. This distinction can be applied to all incoming emergies in the signature. For

example, incident solar radiation is received by the system but the albedo must be subtracted to get the solar energy absorbed.

In the case of water, all the emergy received is absorbed when a sufficient area is considered. So for the United States as a whole, including its coastal waters, all the emergy in the rainfall is absorbed in the system, i.e., used in evapotanspiration, the chemical and physical work of runoff, and the baroclinic circulation of the coastal waters including that supported by ground water flows. The calculation of the emergy absorbed is a function of the boundaries chosen for a given system, where more or less of the emergy received may be doing work in organizing the system. For a mountainous area like West Virginia emergy is received as both the chemical potential of the rain water based on its solute concentration relative to the ground state of sea water and/or the interstitial fluid of plants, and the geopotential of the rain at the elevation where it falls. However, only a portion of this emergy is used in the state.

Silvia Rometelli's work indicated that both the chemical potential in evapotranspiration and the geopotential work of runoff waters on the landscape should be considered as the emergy absorbed supporting the ecological organization of mountainous areas. River and ground water flows carry the remaining chemical and geopotential emergy out of the state. In addition, cross border emergy inflows are added to the emergy received, and the emergy of the outflow subtracted from these inflows to determine the emergy absorbed within the system. Thus, the chemical and geopotential of rivers absorbed in the state would be added to the absorbed renewable emergy base, but only the larger of these two would be counted in the emergy received. The object of all rules to determine the absorbed renewable emergy base for a system is to avoid or minimize double counting of inputs form the three major independent emergy sources to the earth, (solar radiation, the earth's deep heat, and gravitational attraction of the sun and moon).

We believe that the magnitude of the emergy base for a given system is also a function of the area resolution of the study and the averaging scheme used to determine the emergy received and absorbed. For example, areas with distinctly different emergy signatures within the boundaries of a system under evaluation should be evaluated separately and the largest emergy input weighted by area and then the weighted averages summed over the entire area to give a value for the whole. A further refinement is to produce a spatially explicit emergy signature (e.g., defined by 90m pixels) and sum the area weighted renewable emergy inflows over the entire area to determine the emergy base for the system. As the spatial resolution of the inflows increases the total emergy of the whole system area should approach an asymptote defined by the finest scale necessary to resolve the most concentrated emergy inflow. For example 90 meters resolution should allow waves breaking in the shoreline to be counted as a separate inflow, whereas, they might not be counted in broader averaging schemes.

Different rules have been used over time to determine the emergy base for a system, however the same rules for determining the emergy base of a system should be applied to all systems that are to be compared. Increasing the spatial resolution for determining the absorbed renewable emergy base for systems to 90 m resolution will result in an estimate near the maximum renewable emergy received and absorbed by the system. A study of the way that the emergy bases change as spatial resolution is

increased is under way and may result in a relationship that can be used to correct earlier studies.

D. Scienceman : In Environmental Accounting Odum (1996.pp. 196-198) Odum used N = N_0 + N_1 + N_2 = 526 not 600? You only use N = N_0 + N_1. Very confusing.

4. I am sorry for any confusion generated by the definition of terms in the aggregated model Table 9. We used the Texas report as a model for Table 9 and it is set up somewhat differently from the U.S. table in Odum (1996). Please see errata posted at http://www.epa.gov/aed/research/desupp3.html for a discussion of some differences between Table 9 in the West Virginia Report and Table 10-5 in Odum (1996).

D. Scienceman :Your Figure 2 (p. 3-12) shows R_A = 68. But Table 9 (p3-13) item 54 shows R_A = 66.

5. The number for R_A on Figure 2 should have been 66, thus the diagram is in error. I will post this correction on the website. Thank you.

D. Scienceman:. I find your introduction to Emergy very bad.

6. I admit that the introduction to emergy in this report was probably too brief. However, the report had two specific purposes (1) to provide a guide to performing emergy analyses of states, and (2) to present the results of an emergy analysis of the State of West Virginia. Our purpose was not to present a complete discussion of the emergy concept. We could only include so much material in this short report and there are many published books, articles, and reports by Dr. Odum and others that thoroughly present emergy and related concepts.

D. Scienceman:. Do you mean "available energy" = exergy, or energies available?

a. I mean available energy as defined by Dr. Odum (1994): Potential energy capable of doing work and being degraded in the process. In most cases available energy as we measure it is almost the same thing as exergy, which Odum added in parentheses in his definition. However, Odum never fully embraced exergy by incorporating the exergy communities 2nd and 3rd order refinements of available energy into his calculations. I chose not to get into the subject of exergy in this report for several reasons. (1) Available energy as commonly calculated in emergy analysis differs slightly from the calculation of exergy for many quantities. (2) In this report the standard methods put forward by Odum for determining available energy are used. (3) I am currently looking into exergy calculations more carefully to determine whether we should use these calculation methods when determining "available energy". Some scientists in the global emergy community believe that we should.

D. Scienceman:. Kind and type must not be identified with form.

(b) By form I assume that you mean available energy versus the energy of the environment which is unavailable for driving a work process. Available energy of many kinds exists in systems and each kind has different requirements for its creation. In general, each kind or type of energy would be associated with a different transformity.

D. Scienceman the prefix "em" = energy memory (an acronym) is never explained- emjoules are units of energy memories – see emergy algebra – emjoules are units of energy memories. See memory algebra in Environmental accounting (p. 100), (diagram (b)).

(c) I have given your derivation of the word "emergy" in other papers and Odum and others including yourself have also. I often give your "energy memory" derivation of the emergy concept and the word 'emergy" and I regret that we did not incorporate it here. I will post this material on the web site to remedy this.

D. Scienceman:. I now prefer to use the derived units – emergy (semj) = odums (Od) and empower (semw) = lotkas (Lo) and emergy intensity = emity (odums per form joule) etc – all standard physics nomenclature.

(d). Odum used solar emjoule (sej), emjoule (emj) for emergy and sej per unit time for empower. I guess the solar emjoule per sec or sew or semw would be the appropriate physical unit for power. I know that he when back and forth on using semcal and secal in the second addition of Environment, Power, and Society. As long as we are consistent, I am not sure that it makes much difference what the unit designation. Many physical units have multiple abbreviations in the literature (e.g., both sec and s are used for second). With regard to new units for emergy (the odum for semj), empower (the lotka for semw) and transformity or emity (odums per form joule), only time will tell whether such as system will be adopted. Physical scientists are not adverse to naming units after prominent scientists (e.g., the sverdrup for mass transport in the oceans).

D. Scienceman:. I avoid the phrase emergy analysis like the plague. Too easily confused with "energy analysis" - conservation algebra. I choose "emergy synthesis" and "emergy evaluation "I quote Odum (1980) "energy analysis although it is more synthesis than analysis (p.9).

7. Emergy analysis has been used in many publications and is perhaps better known that the related name emergy synthesis. In reality our methodology includes both analysis and synthesis, but emergy analysis/synthesis is a bit cumbersome. For the time being I believe one can use either analysis of synthesis depending on the nature of the primary application of the method in the study being reported. I usually apply the term evaluation to putting numbers on a model, but I see that it might also be used as a synonym for emergy analysis.

D. Scienceman:. I am very alarmed by your use of the phrase "emergy to dollar" ratio. – meaningless – emergy is a concept, dollar is a unit – should be emjoules (unit) per dollar (unit) or emergy to money ratio (13 + mentions)

8. It is perhaps a bad, but longstanding habit, based on Odum's original terminology to refer to the emergy to dollar ratio when we mean the emergy to money ratio. Would solar emjoule to dollar ratio still offend people from other countries with different currencies? Note that the index was correctly defined on page 2-12 as the emergy to money ratio, despite subsequent incorrect uses of the term. As a rule I try to use the appropriate units when writing about the emergy to money ratio (e.g., solar emjoule to euro ratio).

D. Scienceman:. 'Empower density' (p. 2-13) should be areal empower density or 'emergy flow per unit area' - see Odum (1996. p. 173).

9. I agree that technically the measure of interest is the areal empower density, although I think that area is implied by the context and usage of the term. Does pulsing indicate greater emergy density in time?

D. Scienceman I find your use of 'embodied joules' (sejs) (p. 4-1) a disaster – long out of date – only used by Herendeen and Costanza. I quote R.N. Adams (1988) (p. 96) 'marginally it may be noted that the term embodied energy is a most unfortunate label. To be 'embodied' is to be contained within etc.'

10. In my dictionary embody means to invest (provide) with a corporeal form. The transformation of energies required for this process (creation of the form) may be considered as an equivalent measure of it. I agree that other associations with this term are unfortunate, but Odum (1983) initially used it to explain his concept and I feel that his use is within the scope of definitions of the term and that we can use to explain the concept that was eventually defined as emergy. This is not intended to diminish your contribution of the energy memory idea as the basis for the new physical quantity and its new name "emergy". Others define "embodied energy in a different way and therefore, I agree that energy memory is the preferred way of explaining Odum's concept.

D. Scienceman:. I find great confusion in your use of maximum power (p. 2-5)' and maximum empower (p. 2-12) etc – I find incomprehensible.

11 I am not sure what passages you are referring or what is confusing you in them. I suggest that you read the paper from Environmental Science and Technology 35: 2867-2873, which I e-mailed to you. If you are still confused, send be a specific question and I will answer it.

D. Scienceman:. I refer to money as imaginary or symbolic wealth to contrast with real wealth – a clear difference.

12. I like your use of symbolic wealth (money) to contrast with real wealth (emergy). I will think about this further as time permits.

D. Scienceman:. I prefer the phrase "systems energy" (Odum, Zygon 1977, P. 111) versus 'energy systems" (windmills etc.).

13. I believe that the term “energy systems” is more generally used in the literature by Odum and others. I think that “systems energy” would have a different meaning, although I need to think more about it.

D. Scienceman:. No sign of drug estimates in your calculations – illegal?

14. The contribution of drugs such as home grown marijuana to the renewable emergy production of West Virginia is unknown. I had no reason to think that this was a particularly large contribution to wealth. Also, the production of moonshine whisky was not evaluated. The government doesn’t have reliable records of these illegal activities.

D. Scienceman:. Flux is “flow per square unit area perpendicular not identical to flow (p. 4-1)

15. You are right that flux is flow per unit area. The word ‘fluxes’ should have been flows on page 4-1.

D. Scienceman: My conclusion is that the report requires major revisions.

16. One reason that we have included the web site address in the publication is to give additional information on the calculations and to allow a space where errata and alternative explanations, opinions, and comments can be posted. I will add your comments and suggestions under errata and comments on the web site so that others can take advantage of your careful review of the manuscript.