Energy Externalities as Indicators of Ecological Work in Economic Macroprocesses

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Introduction

In the search for understanding environmental economics (especially applied environmental economics) as an integration of economy and ecology, one must be aware of breaking with the conventional view of environmental economics, and perfecting it at the same time. It is what the author attempted in introducing the analytical idea of energy externality (Pillet and Odum [1984, 1987]; Pillet [1985, 1986a, 1986b]). In a simple manner, energy externalities are macro-level, external effects associated with data on energy spectra. They have been called energy externalities because they have roots both in the physical environment and in the economic realm. They link economics to the ecosystem.

The study is in three stages. Firstly, the economic ideas of external effects and environmental externalities are introduced and related to the environmental issue. Secondly, the ecoenergetic ideas of embodied energy (now, emergy) and energy quality (now, transformity) are introduced and related to economics. Thirdly, the concept of energy externality is introduced, defined, and tested as a possible indicator of the role of ecological processes in economic production. Table I charts three successive steps in the theory of externalities since 1920. This summary table allows to go straight to the point as regards the first section (first and second line) and the last (third line on the table). The mid section I pays attention to ecoenergetics.

From Environmental Economics...

Environmental economics is a subdivision of welfare economics. One goal of welfare economics (within the neo-classical tradition) is to allow consumer's utility and production-firm's profit to be maximised under perfect competition and under the general assumption that consumers and producers are satisfied by buying and selling goods in the marketplace (all valuable assets can be individually owned and managed and all participants in the market are fully informed).

Unfortunately, production and consumption may have effects other than direct ones on buyers and sellers in the marketplace. This led to the definition of external costs and benefits (Pigou [1920]; Marshall [1930] - that is, the activities of any (physically independent) economic agent may affect the position

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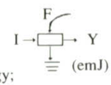
Table I. Summary Table: General Theory of Externalities: Three Basic Concepts

Concept	*Theory*	*Definition*	*Diagraming*	*Modeling*	*Field, Range*	*Principles*	*Application*
Economic, Market Externalities (1920)	Welfare Economics; Marginalist Theory	$Ø = \frac{1}{\lambda_j} \frac{\delta u_j}{\delta \chi ik} \begin{cases} <Ø \\ >Ø \end{cases}$	Graph	Functional Interrelationships; Perfect Competitive Market Micromodels	Nonmarket Measurement of Utility	Utility of Profit Maximization under Budgetary Constraint; Pareto Optimality (Compensative Variations)	*Incidental* External Effects; Nonmarket Welfare Measurement and Policy-making; Cost-Benefit Analysis
Environmental Externalities (1972)	Environmental Economics; I-O Analysis; Accounting Framework	[R], [W] Resource Input, Waste Output; W[C,R{Z=f(X,C})) W, Welfare C, Consumption R, Env. Externalithies Z, Residuals X, Production	Matrix Form	I-O Tables with Fixed Coefficients; (Multi-) Sectorial Models; Welfare Function	Extension of the Economic Paradigm to Include Environmental Links	General Equilibrium; Constant Resource Availability; Application of Physical Principles to Economics	*Pervasive* External Effects; I-O Based Materials Accounting; Taxonomy of Materials by Economic Use
Energy Externality (1983)	Applied Environmental Economics; Systems Ecology; Energy Analysis Procedure (*Emergy* Theory); Ecological Economics	 F/I Emergy Investment Ratio; I/(I+F) Energy Externality Ratio (xE)	Autocatalytic Design; Circuit Language & Energy Diagrams	Macroscopic Minimodels; Microcomputer Simulations	Interfacec Environmental and Economic Systems; Macro-prices	Energy Laws; Maximum Power Principle	*Structural* Importance; *Emergy* Analysis of Environment Economic Systems and Subsystems; Measurement of the External, Energy Basis of a National Economy

Revised version of the table in Pillet (1986 B)

of any other (physically independent) economic agent, without the intervention of the market. Early examples were environmental in nature: sparks from the locomotive engine setting fire to the farmer's field, on the external cost side or, on the external benefit side, the tale of the beekeeper's bees and the orchard owner's apple trees.

The idea of external effects gave rise to the complementary concepts or economic and environmental externalities.

Economic Externalities

An economic externality is defined as the case where a regular action of one economic agent (one consumer or one production-firm) incidentally affects the utility level of another consumer or the production possibilities of another firm in a way that is not reflected in the setting up of the market equilibrium and in the definition of its optimality (Meade [1973]; Just et al. [1982]). In general, policies for dealing with economic externalities are discussed regarding theoretical or applied welfare economics in terms of Pareto optimality (second best solutions), damage functions, or social optimality. In the latter case, an externality is defined in a slightly different way, anticipating the most commonly encountered situation in policymaking - a compensation. A regular activity of any economic agent is said to generate a beneficial or a detrimental externality if this regular activity causes incidental benefits or damages to another agent, and no corresponding compensation is provided for or paid by the one who generates the external effects (Kaldor [1939]; Hicks [1939]).

The theory of economic externalities is concerned with understanding and predicting economic behavior regarding the presence of external effects. With respect to this microtheory of externalities, external effects refer to *incidental* and *temporary* spill-overs.

Applied welfare economics deals with nonmarket measurement of external costs and benefits, and with policies for obtaining social optimality in the presence of external effects - that is, where individual preferences are not completely reflected in observable decisions in the marketplace. An economic externality is properly defined as follows with respect to a consumer (i) - consumer (j) external effect (Buchanan and Stubblebine [1962]; Davis and Whinston [1965]):

$$\begin{array}{l} \text{no spillover;} \\ \text{perfect} \quad 0= \\ \text{competition} \end{array} \quad \frac{\partial u_j}{\partial x_{ik}} \begin{array}{l} > 0 \text{ beneficial} \\ < 0 \text{ detrimental} \end{array} \qquad (1)$$

Equation (1) makes sense as follows: as being measured regarding butgetary constraints, the marginal utility for j of any good (k) consumed by i either is zero due to perfect competition or is influenced due to market shortcomings (or spillovers). In the latter case, an externality exists as far as individual i imposes a gain of utility, or a loss of utility, on j in consuming k, both kinds of effects which are not reflected in the marketplace and consequently not considered in individual utility maximization.

In general, environmental economics is concerned insofar as that the economic externalities are explicitly linked to environmental pollution and similar environmental deterioration Yet, once this link is well established, pure economic externalities turn to environmental ones.

Environmental Externalities

One can define environmental externalities as the case where actions of economic agents affect the production possibilities of the economy and hence the flow of goods and services individuals can enjoy, in a way that is not reflected in the marketplace but that is reflected in real, moneconomic terms. In this sense, the economic microtheory has drifted from a strict price circle to the emerging problem that production and consumption are intimately involved with the real, physical dimensions of resources, goods and services (Boulding [1966]; Daly [1968]; Georgescu-Roegen [1971]; Odum [1971]; Ayres [1978]; Førsund [1972]). Seen from this perspective, externalities are not incidental, potentially internalyzed nonmarket events (which for some reason sometimes happen), but are phenomena that are *inherent* to any economic processes. They take part in the economic use of materials and energy. As a consequence, unlike economic externalities, environmental ones are produced along with economic goods and services.

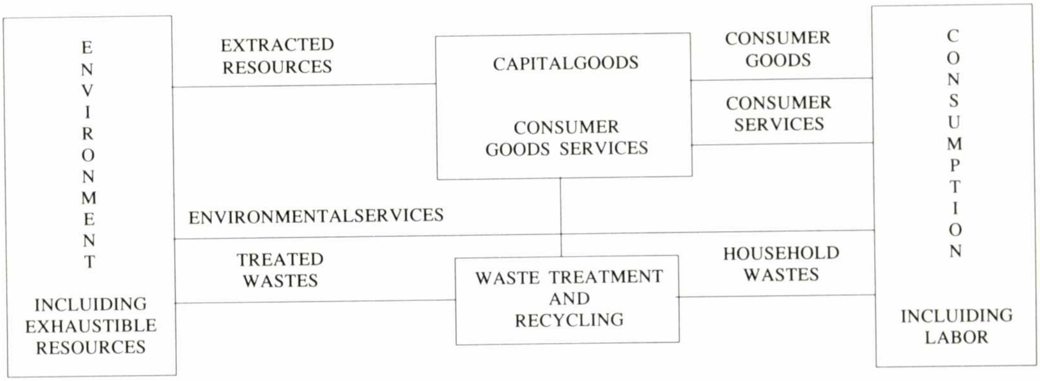
An early attempt to formulate this problem seems to have been that of Daly, though Boulding already outlined some of the basic ideas of environmental economics like that of a finite environment from which economic activities derive stocks and flows of materials and energy for producing goods and services, waste assimilation or environmental quality improvement. The Daly model may be used for showing a simplified input-output model figuring some basic relationships between the main economy and the environment (Fig. 1).

Other attempts focused on input-output models in which the environment was treated as a distinct sector subject to what has been known as the materials/energy balance principle (Ayres and d'Arge [1970]; Noll and Trijonis [1971]; Ayres [1978]). This principle states that the laws of conservation of matter

Fig. 1. Daly's Model. The first sector of this input-output matrix [A] represents the economy acting upon the environment, for example, in driving it or in rejecting waste materials of a vast variety of kinds. Sector B focuses on the economy as a classical production-consumption ageless machine only subject to effective demand. Sector C deals with natural resources direct supply and waste assimilation from the environment as well as adverse effects upon the economy. Sector C focuses on long period environmental work. Pillet [1986b], after Daly [1968].

	ECONOMY	ENVIRONMENT
ECONOMY	B	A
ENVIRONMENT	C	D

Fig. 2. Ayres-Kneese Model. In this input-output model associated with and environmental sector, two successive transformation matrices are involved: a resource/commodity matrix and a commodity/product one. Services involve no physical inputs. Goods are priced as are raw materials extracted from the environment. Waste flows from the final consumption carry a negative price. Recycling is allowed for. Pillet [1986b], after Ayres [1978].



and energy "guarantee that the sum total of all waste flows to the environment from the economy must be equal to the sum total of all resources originally extracted from the environment" (Ayres [1978]). This rule makes sense regarding sectors C plus A in Fig. 1. It can be enlarged to sector B.

As an example of a general equilibrium model including environmental externalities, the Ayres-Kneese model (Fig. 2) is a production-consumption input-output model associated with an environmental sector, both of them being subject to a balance of all physical flows. In general, models of environmental externalities are concerned with the search for optimal policies for economic growth in the presence of resource constraints and a degradable environment.

From this materials/energy balance principle perspective, the economy does not simply go from factors of production to marketable goods and services. Instead, it is a set of transformation into goods and services, before being discarded as partially recyclable wastes. From this point of view, a somewhat more elaborate economic paradigm has been developed in order to include environmental links, and to integrate environmental externalities. In this enlarged economic paradigm, the first stages imply physical transformation and involve human labor and capital whereas the last stages are not physical in nature, but include labor and material products generated in the previous stages.

A formal statement regarding environmental externalities and welfare economics may be found in Førsund [1984] as follows:

$$W[C, R \{Z = f(X,C\}] \tag{2}$$

where
W = welfare function;
C = consumption;
R = environmental externalities;
Z = residuals;
X = production.

Equation (2) is read as follows: "Welfare is derived from consumption of man made goods (C) and environmental services (R). The quality or quantity of R are influenced by residuals (Z) generated by production of goods (X) and consumption (C)".

This kind of conceptual framework leads to external economies macro models.

Yet, expanded economic analysis including environmental links cannot be made extensive enough to capture all transactions of interest. Instead, they open ways to economic-ecologic models.

There is some agreement that economic analysis cannot be much more extensive. Therefore, means for achieving a solution refer more and more to the integration of economy and ecology (e.g., in the search for a comon metric, in defining the economy as a steady-state subsystem of the ecosystem (Daly [1984]), in building biosphere input-output models (Costanza [1984]; Hall et al. [1986]), integrated economic-ecological models (Amir [1987]), extra-market physical model (Schilizzi [1987]) or in favoring energy analysis (Odum [1976]; Costanza [1980]). Unfortunately, some of these attempts are sometimes overreaching the integration of economy and ecology either in fully expanding markets (this case also regards the extension of the economic paradigm to include environmental links) or in substituting physical models and principles to economic ones. The energy externality analysis could avoid these shortcomings.

In this section, we focus on the embodied energy (now, emergy) analysis of economic-ecologic systems. Then, as a third step in the theory of externalities, we deal with energy externalities, expose a case-study in relation with this quantitative analysis, and infer ratios and indices as analytical indicators of the role of ecological processes in economic activities.

Odum's theory of embodied energy and energy quality is here a process for understanding, predicting, and improving the vitality of macroeconomies (Odum [1983a]; Odum and Odum [1983]; Odum [1984]; Pillet and Odum [1984, 1987]). Accordingly, the concept of embodied energy (now, emergy) is used for converting resources outside and inside the economy to equivalents of the same form (that generate them); that is, for putting resources of energy, environment, and economy on a similar basis (taking account of what is actually needed to do the work). Solar joules (now, emjoules, or emJ) are used as a common (source) unit of emergy when discussions are more on environmental processes. Coal equivalents may be used when economic analysis dominates (though uncertainties do not allow to switch safely). Economic activities are evaluated in dollars in the marketplace. Emergy analysis is used outside the economic market evaluation. However, a major strenght of the emergy method is its ability to make evaluations of both ecological and economic macroprocesses on a comparable basis (see Fig. 3). In this case, economic activities are also evaluated in emergy units. In short, one can calculate on both sides of the marketplace the amount of energy (in equivalents of the same form) that is required for economic macroprocesses. This emergy evaluation method lays the foundations of our energy externality analysis. The emergy method under review is also based on the concept of energy quality (now, transformity), which is given by energy transformation ratios.

Fig. 3. Economic activity is priced by the market forces. Emergy evaluation can be used either for environmental products or for economic ones, thus giving the total emergy basis for the economic activity under consideration.

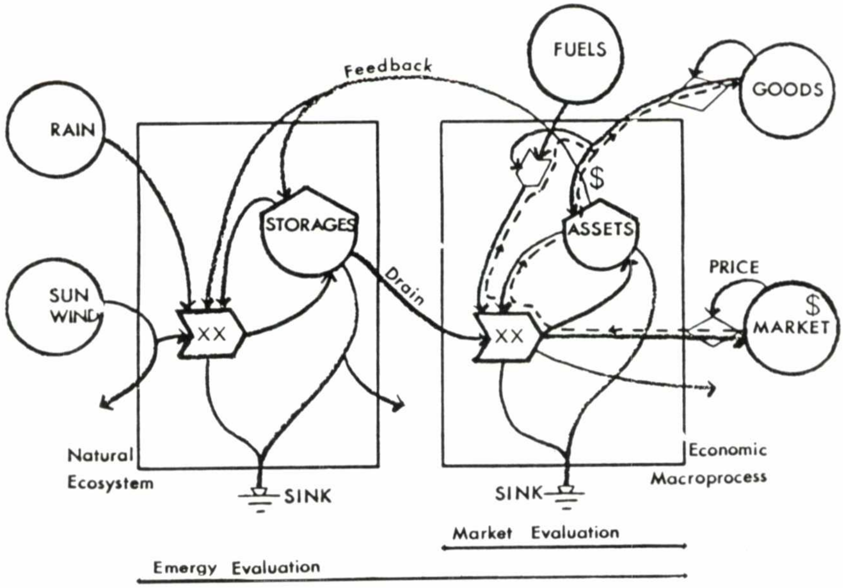
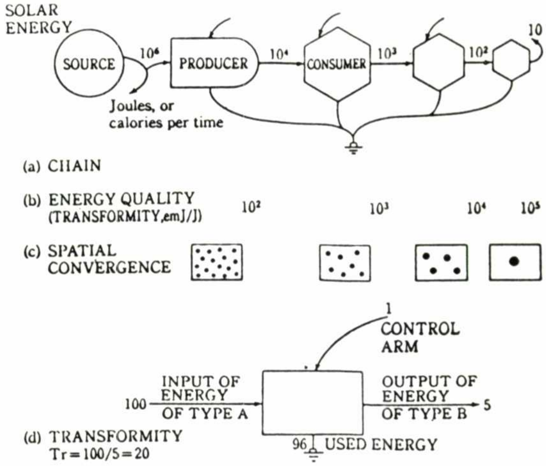


Fig. 4. Transformity measuring energy quality: (a), (b) successive transformations of work in a food chain with actual energy becoming less and less (in joules), but with higher and higher energy quality (or transformity) measured in em J/J; (c) spatial convergence; (d) definition of transformity. Pillet [1986b], after Odum [1983a].



Work - either from the environment or from economic processes - may be considered as the energy transformed from one state to another. Such a work (that is, such an energy transformation) is said to be useful when it feeds back, as it does, for example, in the economy in which it is used. Accordingly, the energy transformation ratio measures the ratio of inputs of the one form of energy, say the solar one, to the outputs of another one, say to organic matter, or of sunlight to electricity, and so on (see Fig. 4a). More strictly, this transformity between the one form of energy and another measures the amount of the second form of energy relative to the first. It tells how much joules of type A are embodied (or, are equivalent) to 1 joule of type B (see Fig. 4d). For example, the transformity of the sun is 1, that of the wind is 663 embodied solar joules per joule, and that of electricity is 15.9E4 embodied joules of sunlight per joule of electricity. We are now used to reading these ratios as follows: 663 emJ/J, 15.9E4 emJ/J, and so on.

It follows that, if the work transformation under review has the above-mentioned amplifying feedback, the transformity is the (idealized) maximum useful power through that process according to open system thermodynamics (Odum [1983a]). In this sense, the transformity becomes a property of successive transformations of work (in ecological chains and in economic sets of processes as well). What is observed is that these "successive transformations of works, each feeding forward and back, become less and less in actual energy, but with higher and higher quality in the sense of their amplifier feedback role per unit energy" (Odum [1983A]). A transformity ratio is a measure of energy quality (at maximum power loading - see Fig. 4b).

Thus, energy quality is also a measure of the energy hierarchy in a web of transformations from low-quality inputs to high-quality outputs; that is, from the work of the environment to the output of macroeconomies.

Finally, between the natural ecosystems and the economic macroprocesses, there is an overall ratio of dollar flow (as measured by the gross national product) to emergy flow. This emergy/$ ratio (now, monergy) is the transformity of a given macroeconomic activity (one cannot speak of joules/$ or joules/F; we really refer to emJ/$ or emJ/F, and so on). For example, the monergy of a country is obtained by dividing the solar emergy used within the country by the gross national product of this country (in US$, NZ$, SFR, or any other currency unit). For example, this produces a ratio of 3.0E12 emJ/$ (1980) for New Zealand; for Switzerland a ratio of 0.72E12 emJ/$ (1983); and for the USA 1.85E12 emJ/$ (in 1982) (Odum and Odum [1983]); Pillet and Odum [1984]). In turn, these ratios are used for evaluating human services, and not those of nature, as far as money only renumerates human labor.

The unit of monergy is the emdollar, initially put at 3.8E12 emJ per US$ of 1980 by H.T. Odum and D. Scienceman (according to the latter, the number of solar emjoules used to define an emdolar should be internationally and historically invariant, of use as a unit for comparing dollars in different times and places). It follows that the monergy of any other year (as regards the USA), or country, may be expressed relative to this standard (the number of emdollars for the economy of New Zealand in 1980, of the USA in 1982, or of Switzerland in 1983); that is 0.79 em$ for New Zealand (1980), 0.49 em$ for the USA (in 1982), and 0.19 em$ for Switzerland (1983).

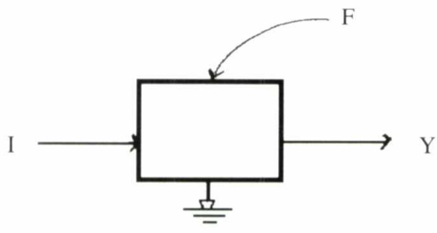
Energy Externalities

As indicated earlier, energy externalities have roots both in economics and in ecoenergetics. In short, they constitute a new concept in the economic theory of externalities, but their measurement belongs to the emergy analysis of environmental-economic systems (according to the theory of emergy, the term should be emergy externalities in just the same way that external effects should be named external emeffects; we suggest to speak of energy externalities as a rule, and of emergy externality ratio or of external emeffects only when the case arises).

Firstly, energy externalities may be defined in a generalized way as the ultimate sources that generate economic macroprocesses through pathways of action that are indirect and even unrecognized within the economic realm (Pillet and Odum [1984]; Pillet [1986b]). Energy externalities are thus real, macro-level, unpriced contributions to macroeconomies - they are external emeffects. At the level of the biosphere, energy externalities make 100%. At the level of economies, the emergy analysis can be used for evaluating those effects, since the market pricing mechanisms do not care of external effects or reources.

Secondly, energy externalities may be conceptually defined as the ratio of economic use that is free within environmental-economic systems, or as the ratio of no cost economic miscontributions to the environment within environmental economic systems.

In this case, a formal statement is as follows:



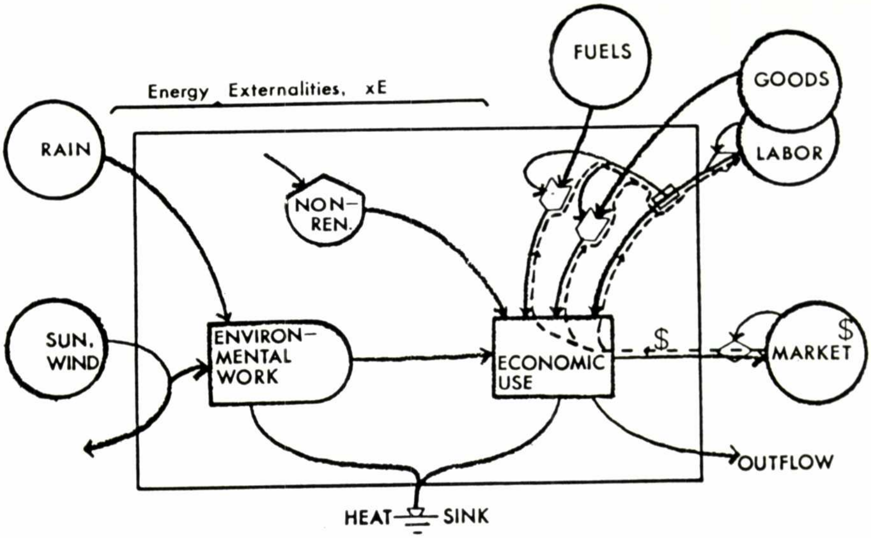
$$xE = I/(I+F) \tag{3}$$

where
xE = energy externality (or, emergy externality ratio);
I = energy externalities (flow), or unpaid inputs (measured in emergy units, or emjoules);
F = high-quality inputs; that is, goods and services bought in the marketplace (as measured in emJ);
Y = high-quality output to be sold in the marketplace (as measured in emJ).

The fact is that the vitality of an economy does not only depend upon the productive work of people and machines, but also depends upon the productive work and the carrying capacity of the ecosystems. So useful production work includes that of people inside the economy, plus that of natural systems interfaced with economic processes. Thus, there is some hidden relationship between the energy basis of an economy, on the one hand, and the marketable inputs and outputs, on the other hand. Because neither labor is spent nor price is paid, environmental contributions to economic macroprocesses cannot be evaluated on a dollar basis (Fig. 5). Therefore, the emergy method is used for evaluating those externalities which, in turn, may be put on a monetary basis by their proportionate effect on the total money that measures the national income. In this way, as David Pearce [1987] puts it, economists can "anchor" things outside markets to things inside markets.

This environmental-economic systems analysis is a way for exploring, understanding, evaluating, and predicting the real, external environmental basis of economic activities, with energy as a passageway. It takes into account both energy laws and economic principles in order to improve the vitality of environmental and economic systems. To sum up, the question is: How much do energy externalities participate in any of the economic macroprocesses?

Fig. 5. Energy Externalities Vs. Purchased Inputs.



Case-study

Let us consider, as a case study, the analysis of the economic subsystem wine production in Switzerland, featuring its typical energy externality.

The Swiss vineyard uses 13,885 ha (a little bit less than 1% of the total farming area). The must (or, unfermented wine) yield is over 1 million hl per year and has dramatically expanded over the last five years (data used are for 1983, mainly from the Lake of Geneva Region; Pillet [1987]). 75% of the vineyard and 85% of the yield are located in the Western, French-speaking Switzerland.

We shall now summarize the emergy analysis of the environmental role and the measurement of the energy externality in the Swiss vineyard cultivation and wine production.

The energy flows to the Swiss vineyard and the production of wine are portrayed in Fig. 6. Each pathway is calibrated in emergy units (1E13 emJ/ha/yr). Calculations appear in Table II. Firstly, actual

Fig. 6. Swiss Vineyard and Wine Production. Energy diagram. Data are in 1E13 emJ per ha per year.

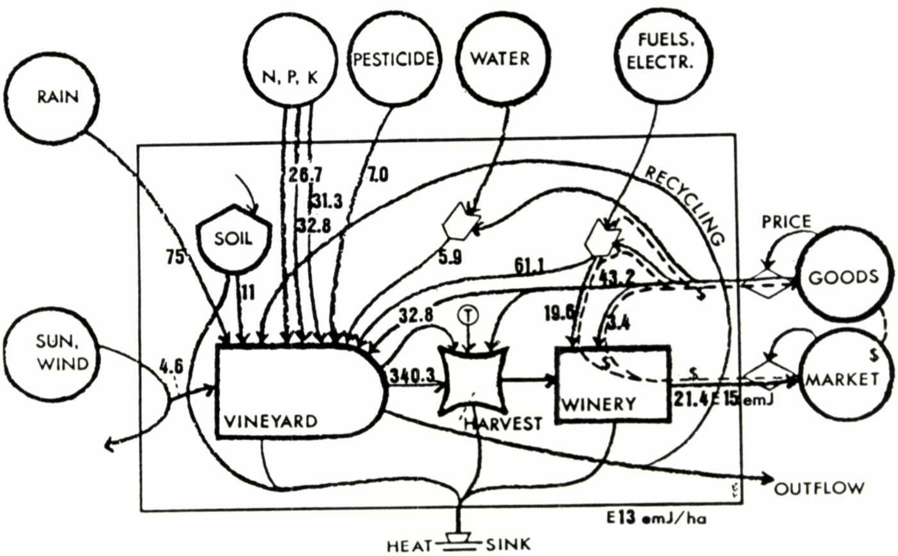


Table II. Energy Flows per Hectare and per Year in Vineyard and Wine Production. Lake of Geneva Region

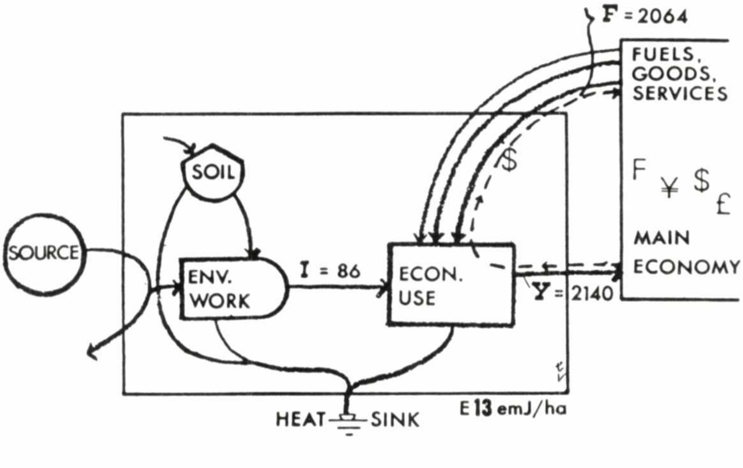
1	*2*	*3*	*4*	*5*
	J	*emJ/J*	*1E/3emJ*	*emS*
Direct sunlight	4.6 E13	1	4.6	-
Rain	5.0 E10	1.5 E4	75.0	6.25 E3
Soil used up	17.6 E8	6.24 E4	11.0	9.17 E2
Organic matter	1.02 E9	6.24 E4	6.4	-
Irrigation water	3.95 E8	1.5 E5	5.9	
Nitrogen	15.2 E4	1.69 E6	26.7	
Potassium	11.93 E4	2.62 E6	31.3	
Phosphate	9.61 E6	4.14 E4	39.8	
Pesticide	10.64 E8	6.6 E4	7.0	
Direct Fuels	9.25 E9	6.6 E4	61.1	
Steel in machinery	1.81 E4	1.01 E4	18.3	
Iron wares, stakes	3.25 E4	1.01 E4	32.8	
Services	$6 E3	.12 E12 emJ/$	72.0	
Grapes yield	4.74 E10	7.18 E4	387.0	
Sugar added	6.66 E9	8.16 E4	55.9	
Electricity	1.23 E9	15.9 E4	19.6	
Water	1.11 E8	1.5 E5	1.7	
Capital	$2.3 E4	.72 E12 emJ/$	16.6 E15	
Services	$1.02 E3	.72 E12 emJ/$	73.4	
Wine yield	3.3 E10	6.7 E5	21.4 E15	

(1) Energy forms; (2) Actual content; (3) Transformity; (4) Emergy; (5) Macro-price based on the monergy of environment in Switzerland, 1983.
Revised version of the table in Pillet [1987].

energy is measured in joules (column 2) for each pathway. Secondly, the transformity (solar emJ/J) of each category of flow is reported in column 3 (Odum and Odum [1983]), or is expressly calculated (grapes and wine in this case). Finally, the emergy (in emJ) of each energy flow is obtained as the product of the actual energy times the corresponding transformity ratio (column 4). Last, emergy values are reported on the vineyard and wine production diagram (Fig. 6).

An aggregated three arm diagram, calculated from data in the table can be used for calculating useful ratios (see Fig. 7) and to help interpretation.

Fig. 7. Swiss Vineyard Cultivation and Production of Wine. Aggregate view from Fig. 6 used for calculating ratios and to help interpretation. I = energy externality flow; F = purchased inputs; Y = marketable output. All data in emergy units.



1) Net Emergy Yield Ratio

The net emergy yield ratio is defined by Y/F (Fig. 7); that is, the emergy of the output divided by the emergy of the inputs to the process which is fed back from the economy. The ratio characterizing the Swiss wines is 1.04. In comparison, the net emergy yield ratio characterizing Lousiana sugar cane production and sugar processing to ethanol is 1.05 (Odum and Odum [193]). That of Japanese rice sake is 1.06 (Pillet and Murota [in preparation]). This suggest a rather high percentage of purchased inputs with respect to the product yield. It is a rather low yield ratio.

2) Emergy Investment Ratio

The emergy investment ratio is defined by F/I (Fig. 7). It is the ratio of the emergy fed back from the economy to the emergy inputs from the natural environment. The ratio characterizing the wine production in Switzerland is 24.5 (as given by the Lake of Geneva Region wine production). It is 21.2 as regards the Louisiana analysis, 17 with respect to the Japanense sake case-study, and 25 for the U.S. agriculture in general. This confirms the intensive use of high-quality energy inputs in comparison with the use of low-quality environmental ones. It is a rather high investment ratio.

3) Emergy Externality Ratio

The emergy externality ratio is given by I/(I+F) - see Fig. 7 and equation (3). It is the ratio of use that is free. It is ca 4% as regards the Swiss wine production, 4.5% in the Louisiana study, and 5.6% in the case of the Japanese sake. This ratio is a rather low one, compared to the same ratio calculated for Switzerland as a whole (16% - though dissimilitudes do not really allow to switch).

4) Environmental Macro-prices

As a forth indicator, a macro-price for energy externalities may be envisaged by dividing the emergy value of the latter (emJ) by the monergy of environment if this ratio exists or by the monergy of the country (emJ/$). We calculated elsewhere for Switzerland the former at .12E12 emJ/$ and the latter at .72E12 emJ/$ (Pillet and Odum [1984]). Therefore, we can establish a macro-price for energy externalities in the Swiss vineyard at 7.17E3 em$/ha for 1983 (see column 5 in Table II), when based on the monergy of the environment in Switzerland, and at 1.19E3 em$/ha when based on the US monergy of Switzerland as a whole. In comparison, based on the US monergy in 1980, the macro-price of the energy externality flow to Louisiana sugar-cane-ethanol may be calculated at 3.64E2 em$/ha. Note that in Switzerland, there is 5 times less emergy per $ than in the United States. As a consequence, if we relate the Louisiana macro-price to the Swiss monergy, we obtain 1.83E3 em$/ha as regards the sugar cane and ethanol production. Unfortunately, we have not yet calculated the monergy of Japan; therefore, we cannot make comparisons with rice growing and sake making (Pillet and Murota [in preparation]).

To sum up, the Swiss vineyard is producing too much wine on the marketplace, at very high and hard to reduce costs. In reality, this production is based on a rather bad emergy yield ratio and a low external environmental contribution.

Conclusions

Today, there is a need for a better understanding of the relationship between environmental and economic realms. From an economic viewpoint, it is urgent to put quantitative meanings upon external, environmental contributions to economic macroprocesses.

In this paper, we have shown how to formulate a new, workable principle for interlocking economic and ecoenergetic analyses. We called it energy externality because it carried energy meanings while designating environmental contributions as being external to their economic use.

From a theoretical point of view, the concept of energy externality leads the economic theory of externalities one step further. From an applied environmental economics viewpoint, it initiates the quantification of external emeffects (energy externalities) participating in the gross product of economic subsystems. Finally, from an economic and social planning perspective, this concept could help in devising suitable indicators of the role of environment in economic macroprocesses.

Generally, as far as ecological economic analysis is concerned with the following question: How much does the environment contribute to economic products? any information on goods and services provided by natural and semi-natural ecosystems may become economic information within adequate economic frameworks.

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