AN EmERGY EVALUATION OF THE CENTRAL AMAZON TOWN OF ITACOATIARA, ITS PLYWOOD AND VENEER INDUSTRY AND THE FLOODPLAIN OF THE MADEIRA RIVER BASIN

by

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A THESIS PRESENTED TO THE POST-GRADUATE PROGRAM IN BIOLOGICAL SCIENCES OF THE NATIONAL INSTITUTE FOR AMAZON RESEARCH (INPA) AND THE UNIVERSITY OF AMAZONAS (FUAM) IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ECOLOGY

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by
Vito Comar
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The plywood industry of Itacoatiara, its relationship to the town in terms of labor force, assets, goods and services, and the relationship between industry's timber extraction and the floodplains of the Rio Madeira, as well as industry's relation to outside markets, were studied.

In the first part of the thesis the eMergy evaluation developed by Dr.H.T. Odum and his research team is introduced in the context of present trends of economic thought, and its methodology is defined. EMergy refers to the embodied energy, or the solar equivalent energy, represented by each item considering all of the energy transformations that have gone into producing it from primary energy sources. To be able to define the plywood industry and Itacoatiara within the national scenario an eMergy evaluation of Brazil was carried out. It showed a decrease in eMergy buying power from the last evaluation (done in 1983 by H.T.Odum and E.C. Odum), from an eMergy/money ratio of 6.9 E12 sej/$ to 6.08 E12 sej/$, using 1989 data for Brazil. Brazil is also a "resource provider nation with a net eMergy loss from

trade: much value is exported in mining, timber and agricultural products with little energy returning in monetary payments.

The eMergy evaluation was then applied to a case study of Itacoatiara by following the path of sawn logs from forest floodlands through transport and processing, and finally to sales, tallying eMergy inputs at four selected sections within the process. Various eMergy indices, such as Net eMergy Yield Ratio and eMergy Investment Ratio, were calculated. A comparison was made between log felling and transport eMergies with the eMergy value of dollars paid by industry for logs FOB Itacoatiara resulting in eMergy expenditures 12.25 times higher than the eMergy value paid in dollars by industry. Considering the average export timber price for logs in 1989, which was less than half that paid by industry, the eMergy expenditure would be 31 times higher than the dollar eMergy value. This difference denotes the inability of money to represent a true measure of energy expenditure and of real costs.

In the second part macroscopic minimodels (defined in the simulation section) were used to simulate the various components within the town and their relation to the timber extraction area, which was mainly river floodlands ("várzeas", in Portuguese). Simple programs in the "BASIC" computer language were used. The first model used energy flows among system components and between these components and external factors such as natural sources, sources of goods and services and outside markets for plywood products. The second considered eMergy flows and storages of these same components and sources.

The system experiences a great loss in eMergy as industry sends out finished products and money revenues, and maintains its structure. This kind of drain is characteristic of "boom and bust" extractive economies. The eMergy value for the plywood and veneer exported is 31 times higher than the amount paid by the importing countries.

A series of alternative scenarios indicates that substantial improvements in local welfare are possible if less of the monetary value of the wood products are drained from the system and if people lived in smaller settlements. The results support the arguments of Brazil and other developing countries that the terms of trade prevailing in the current economic system are grossly unfair. They also raise the question of what institutional changes and guarantees would be necessary to have fairer (i.e.: higher) international prices for raw materials result in sustainable use of the resource rather than merely speeding its destruction, once even existing legislation for reforestation has been neither obeyed nor enforced.

INTRODUCTION

Deciding how to administer natural resources in the best interests of the human population is one of today's most critical issues. There is an urgent need for integrated studies of human and natural processes, and for the development of management strategies that recognize and promote the vital connections between the two. The disciplines of economics and ecology should not work in isolation from each other in approaching the problems we are facing. Questions such as optimizing the usage of resources, the egalitarian administration of the international economic market, the over exploitation of natural resources, the loss of biodiversity , or climatic modifications cannot be solved focusing on isolated aspects of a major concern. A wider vision is necessary. The systems of man and nature must be integrated without treating human activities and the biosphere's productive processes as separate entities, the one having absolute domain over the other. A new paradigm for this type of evaluation is emerging. In the same way as distinct economies of individual nation states are being woven together within a world economic system, it is becoming clear that economic well-being and ecological stability depend on the establishment of an interface between ecology and economics.

Solutions will not be found in the study of symptoms resulting from interactions between human cultures and nature within the strict confines of separate scientific disciplines, but within a holistic approach that integrates man and nature in symbiotic and sustainable patterns for their common future.

An evaluation of the Emergy, written with M, or embodied energy in the various components and processes of ecosystems (Odum, 1983; Odum and Odum, 1983) clarifies the interdependence between human economy and natural systems, where energy is used as a common denominator to measure activities in both types of systems. Sometimes it is convenient to think of Emergy as energy memory. The evaluation of the main Emergy flows provides quantitative measures of the ecologic and economic system of the area under study. Decisions on the usage of natural resources cannot be correctly taken using money, as money is just paid for services provided, inasmuch as a comparison amongst environmental alternatives can be made using Emergy as a metric. The global scheme in this economic view includes the economy of nature and its inputs (see Figure 1b).

Lack of theoretical knowledge and reliable data is an aggravating factor to the constant drain of natural resources of the Amazon Basin, leaving it with ever-diminishing values. This is especially so with the timber extraction and export industry. Timber resources have never been replaced up to now and methodologies that establish a quantitative system of values that realistically represents biological cycles and human interactions within ecosystems are in urgent need. This thesis uses Howard Odum's eMergy evaluation and modeling as a methodological tool to address this question. The eMergy evaluation is also useful as a means of integrating various disciplines starting from an ecological perspective and a biological background based on energy flows within ecosystems and between them and the human activities they support.

Timber extraction in the State of Amazonas

According to the almost 30 year old (1965) Brazilian Federal Forestry Code, Articles 19, 20 and 21 of Law No. 4.771/65 and relative regulations, forest reposition is a legal obligation. At present, after a series of amendments, for each cubic meter of extracted timber a minimum of 6 trees must be planted. This law is neither obeyed nor enforced. There even exists a Federal Fund for reposition of forest stocks, but during the last 40 years the State of Amazonas used 30 million trees (officially declared figures), of which only 3.2 million were replanted (Jansen, 1991). According to Jansen (1991), 4 million trees should be planted yearly to reach a state of equilibrium between extraction and reforestation.

In their evaluation of timber consumption and obligatory reposition of timber stocks in the State of Amazonas Jansen and Alencar (1991) showed that:

- Federal Government's revenues from this reposition fund are small and poorly paid;
- up to 1991 only 12.81% of what should have been planted had actually been planted, there existing a deficit, just considering declared values for extracted timber, of approximately 30,367,170 trees, accumulated over a period of 23 years;
- although declared timber consumption rose 14 times in 40 years its prices fell 4 times in the same period;
- starting from a cross-information matrix of 40 years of official data collected by 3 institutions (SEFAZ, CODEAMA, IBAMA), we now know HOW MUCH, WHAT and WHERE to plant. Legislation is also not followed because this information matrix is mostly unknown to the public;
- the use of timber resources in the state of Amazonas is done in a predatory fashion. Such resources have not been factors of enrichment of local populations, nor have they generated revenues for their recomposition;
- the incapacity of the Executive bodies to at least implement the reposition of the quantity declared to have been consumed is factually established. Also timber volumes of the undeclared proportion are unknown.

" When obtaining an economic resource implies in its extinction, or when the speed of recuperation of this resource is inferior to the speed of extraction, we have what is termed 'extractivism by annihilation'" (Homma, 1982, cited in Jansen and Alencar, 1991). Homma cites timber extraction among other examples.

The present emphasis given to agriculture, without considering the use of the capital of natural resources and the lack of agricultural vocation of the environment, is another negative factor in the depletion of forest assets (Jansen and Alencar, 1991).

The selective exploitation of timber species in greater demand (Bruce, 1976) is also a menace and this genetic impoverishment cannot be detected by satellite images and remote sensing techniques (Santos, 1987). The most threatened timber species in the state of Amazonas are found in the lowland forest areas ("várzeas" in Portuguese), where extraction has traditionally taken place for centuries, using the natural rise and fall of the waters. Várzea areas supply the greatest timber volumes for industry (Jansen and Alencar, 1991). As little or no data are available for these forest ecosystems (Barbosa, 1987, cited in Jansen and Alencar, 1991), modeling techniques and the eMergy evaluation methodology can offer here a substantial contribution.

Among other measures such as seed-banks, seed technology, vegetative propagation studies, and planting of the most consumed species, a series of binding obligations for government agencies and private enterprise to implement the Federal Forest Reposition Fund through a reforestation plan for the state of Amazonas, Jansen and Alencar suggest the integrated study of silviculture and forest management practices in selected várzea areas. These areas should be close to rural populations and should aim to provide them with ecologically sustainable development alternatives. They also alert about the socio-political dimensions of the question where lack of land titles, educational and health facilities limit the willingness of local riverain people to invest in replanting. They rather migrate to increment the informal economies and the slums of urban areas (Jansen and Jansen, 1982).

Another factor against the application of sustainable forest management is represented by the existence of high discount rates, above 10%, where sustained forest management cannot compete with other investments or financial returns such as stock exchanges and real estate speculation. New ways of evaluating forest values and new sustainable development proposals must be formulated. Basic institutional restructuring and functional changes in the economics of forest management must take place (Fearnside, 1993). Once again the case is made for the use of the eMergy evaluation as a tool for a new system of values that tie economics to ecological processes and human production methods.

The present study provides a simplified structure to evaluate the timber extractive industry that uses várzeas's extractive areas as a system and evaluates the Itacoatiara plywood industry. It identifies the main functional components of this system and their relationships, and interprets results in terms of the system behavior as a whole. It thus hopes to offer elements for a sustainable use of forestry resources as a development alternative to local populations. The eMergy evaluation is here used as a methodological tool to:

1. measure the present embodied energy, or eMergy, flows into, within, and from the system of Itacoatiara's timber catchment area and its plywood mills;
2. evaluate the relative contributions of natural and man-made resources to the plywood production process;
3. extrapolate present trends by an eMergy simulation model within different possible scenarios;
4. provide guidelines for defining town size and dimensions of timber catchment area within the environment's carrying capacity.

It is important at this stage to consider urban systems in relation to natural resources.

Urban systems and natural resources

The investigation of the impact of urban systems on the environment of Central Amazonia related to the use of energy and natural resources in the productive, commercial and subsistence processes is of great interest today, since historical processes are forcing human populations to constitute larger urban settlements (Bunker, 1985; Sachs, 1986). The maximization of the usage of resources or the waste of natural and produced energy sources, the integration of the components of the urban system in this equation, and the spatial pattern of development of the town due to these relationships are critical factors to be analyzed.

Through the structuring, diagramming and monitoring of urban energy systems their behavior over time can be observed. The process of evaluation for public decision-making should be based on the weighing of benefits and/or losses resulting from the use of resources (Postel, 1990).

The evolution of models that represent realistically the complexity of different urban systems is a constant challenge for urban designers and planners. Urban systems are not evaluated through a common indexing measure applied both to the internal processes within a city and to the energy contributions from the natural environment. The impacts on this ecosystem are also unrelated to the real energy costs that produced them. Studying the energy resource flows that connect urban activities to their natural environment, on the basis of a common indexing measure, can help define present distortions in urban systems.

Systems analysis concepts, energetic principles and computer simulations are used in the present study to help understand the character, quality and quantity of resource and energy flows which interact within the urban system and between it and the natural environment. The embodied energy, or eMergetical, approach, together with model simulation represent a dynamic instrument capable of identifying trends and helping in the evaluation of different urban development alternatives.

The mechanistic paradigm

The transition from the feudal production mode to the capitalistic one, in the XVI century, saw the birth of the mechanistic paradigm. It was based on a value system that was anthropocentric, competitive, individualistic and submitted nature to man both in its usage and in scientific approach (Heilbroner, 1987). Growth, as a quantitative phenomenon, became synonymous with development. These values are still supporting the present methodologies for the measurement of development. Macroeconomic variables, such as the annual increment of the Gross National Product (GNP), or the income per capita, input just the value of the production costs and of the human labor expended for goods and services. Economy does not recognize, at present, the value of any production processes other than the human ones (Odum, 1972; Capra, 1982).

Although the application of mechanistic values did result in the betterment of sanitary conditions in certain regions of the planet, in the growth of the supply of goods and services to a market that can afford to buy them, in advances in transport and communications systems reducing distances and cultural barriers, in a better understanding of natural systems through scientific investigation, its continuation as the dominant approach in socio-economic behavior and its tecno-scientific applications will take us to the complete unbalance with our environment (Buarque, 1990).

At the moment, both among countries and among social strata, income distribution (derived from the application of mechanistic values) is very uneven and 60% of the world's population lives in precarious conditions. This indicates that this socio-economic and administrative world model is at a deficient and is a failure.

This negligence in managing both human and natural resources has weakened social structures, exhausted sources of resources and handicapped essential ecosystems, extinguishing species and undermining the delicate biotic and climatic equilibrium of the planet.

"Ecological conscience made clear that, on the last account, the ecological limits to uninterrupted economic growth can manifest themselves through undesirable and dangerous alterations in climate and in the main natural cycles (Sachs, 1986)."

A revision of economic concepts and of the value systems that sustain them becomes important here.

Economics and values

Economics is defined as a discipline that deals with production, distribution and consumption of wealth. It tries to determine what is considered valuable at a certain moment by studying the relative values of the exchanges of goods and services. Thus economics is, among the social sciences, the most normative and most clearly dependent on values.

Present economics is characterized by a reductionist and fragmentary approach of most social sciences. In general, economist don't recognize that economy is but one of the aspects of a whole ecological and social context: it is a living system made up of human beings in constant interaction with their natural resources, most of which are, in turn, constituted of live organisms.

The triumph of Newtonian mechanics in the XVIII and XIX centuries established physics as the prototype of a 'heavy' science by which all other sciences were measured (Capra, 1982).

Another aspect of economic phenomena, which is crucially important but seriously neglected by economists, is the dynamic evolution of the economy. Economic systems are in continuous change and evolution, depending of the equally changeable ecological and social systems within which they are set. To understand them we need a conceptual structure capable of continuously changing and adapting to new situations.

Adam Smith and Thomas Malthus had foreseen the exhaustion of natural resources, mainly agricultural lands, due to industrial and demographic growth (Smith, 1776; Sunkel and Paz, 1976). David Ricardo proposed freeing international commerce and the usage of better cultivation techniques to postpone the 'stationary state' resulting from the lack of cultivable lands, or natural resources, but confirmed its irreversibility. The historic vision of Karl Marx, where the means of production transforms the relationships man to man and man to environment in the dynamics of time, and where work is seen as the common indexing measure, although still anthropocentric, puts him in the frontier between the mechanistic and the holistic paradigms (Oliveira, 1993).

The evolution of a society, inclusively the evolution of its economic system, is intimately connected to changes in the value system which serves as a basis to all its manifestations. Once the set of values and goals is expressed and codified it will constitute the structure of perceptions, intuitions and options of that society to promote innovation and social adaptation. As the cultural value system changes, frequently in response to environmental challenges, new patterns of cultural evolution emerge. The study of values is then of great importance for all social sciences as a social science 'exempt from values' cannot exist (Capra, 1982).

" Pleasure and suffering are undoubtedly the ultimate object of economic calculations. To satisfy to a maximum our necessities with the minimum effort ...., or, in other words, to maximize pleasure, is the problem in economy (Jevons, 1988, cited in Capra, 1982)."

Although mathematically one cannot minimize one factor and maximize another at the same time, the above statement typifies today's economic attitudes. Economists, in an attempt to endow their discipline with scientific grounding, avoid systematically the question of non-enunciated values. The only values that figure in today's economic models are those that can be quantified through the attribution of monetary weight (Capra, 1982). This emphasis on quantification confers economy the appearance of an exact science. At the same time, however, it severely restricts the scope of economic theories as it excludes qualitative distinctions which are fundamental to the understanding of the ecological, social and psychological dimensions of economic activity. For example, energy is only measured in kilowatts, independent of its origin. No distinction is made between renewable and non-renewable goods. Also, the social costs of production are added as positive contributions to the Gross national Product.

" Ambitious economists elaborated elegant mathematical solutions for theoretical problems with little or no relevance for public matters." - Washington Post, 20th of May 1979 (cited in Capra, 1982).

" I believe that we economists caused great damage in recent years to society in general, and to our profession in particular, by pretending to hold more than we could really offer." Milton Friedman. 1972. Annals of the American Economic Association Conference (cited in Capra, 1982).

" What economists must do with the maximum urgency is to reevaluate all their conceptual basis and recreate their models and fundamental theories in conformity with this revaluation. The present economic crisis will only be overcome if economists would accept to participate in the change of paradigm which is taking place in all fields. Just as in psychology and in medicine, the substitution of the Cartesian paradigm for a holistic and ecological vision will not result in new approaches which are less scientific, but, on the contrary, will make them compatible with the new conquests in the natural sciences." (Capra, 1982).

Modern macroeconomy, Keynesian in origin, studies the global functioning of the economic system as a set of dynamic interactions between producers and consumers. The global scheme of a capitalistic economy from this viewpoint does not consider the government or the external sectors as separate agents and can be presented as follows (Fonseca, 1991):

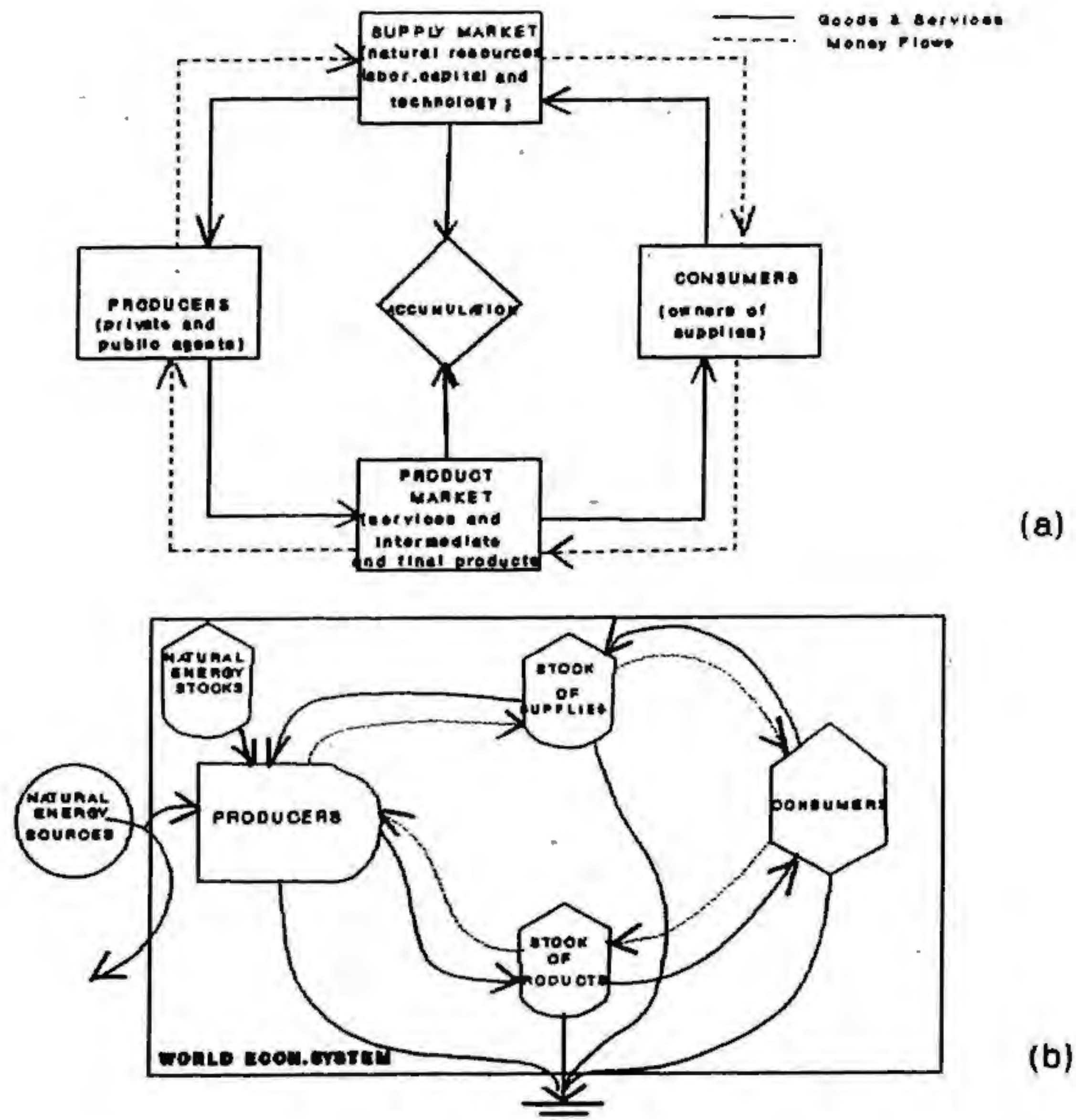


Figure 1. Comparison of traditional world economic view and Odum's conception.

As accumulation occurs, the stocks of all supplies, with the exception of stocks of natural resources, increase. Inasmuch as the regeneration of all other supplies (workforce, technology and capital) is controlled by humans, the reposition of the stocks of natural resources is regulated by the dynamics of terrestrial ecosystems. Any increase in accumulation of stocks represents a proportionally greater decrease in the volume of natural resources. The speed of renewal of natural resources by nature is greatly inferior to the speed of industrial growth. This fundamental factor is not accounted for in the Keynesian model nor in any known macroeconomic model (Oliveira, 1993).

In the Keynesian model additional investment from the State will always increase jobs and, therefore, the total level of income, which in turn will cause a greater demand in consumer goods. In this way investment will always stimulate economic growth and will increase national wealth which will finally trickle down to the poor. The Keynesian model is today inadequate as it ignores many factors which are fundamental to the understanding of the economic situation. It concentrates on internal economy by dissociating it from the global economic network and despising international economic agreements. It also neglects the political power of multinational enterprises, does not pay due attention to political conditions and ignores the social and environmental costs of economic activities. For these reasons it cannot formulate realistic forecasts (Capra, 1982).

Different methodologies for environmental impact tried to develop an integrated approach to the various processes involved such as identification, measurement and prediction (Canter, 1966; Munn, 1979; Shopley and Fuggle, 1984). Economic cost and benefit analyses have been applied to these approaches to evaluate transactions of resources (Westman, 1985). Even if the price of an environmental service is taken as positive, the source of real value is seen as subject to individual will and unrelated to objective human needs, or needs of other species that are considered as biological entities intertwined in ecological communities and social systems. How can we therefore evaluate environmental services and how can we integrate these values within decision-making processes?

The systems of social accounting since François Quesnay to the present have not accounted for the stocks of natural resources (Rossetti, 1991). Social accounting, within macroeconomies, does not recognize work done by ecosystems in the production of resources, the so called "economy of nature", so much so that in the methodology of added value (Fonseca, 1991) the cost of raw materials, as long as not used by the economic system, is nonexistent, and does not hold any intrinsic value prior to its use by man. Unhappily, this macroeconomic vision served as a basis to the institutionalization of a set of political and socio-cultural economic indicators adopted by the United Nations to measure national development. All these indicators are just quantitative and do not measure the impact of economic activities on the environment.

Evaluating development

The above mentioned problems have been aggravated by the formulation of short and long-term economic policies that disrespect the planet's contribution to our well-being, as these economic policies return nothing to a natural system that has its limits (Odum, 1983). These considerations have impelled new directions both in the conception of new values and in a more audacious and creative scientific approach with practical applications. It is the emerging 'holistic paradigm' (Capra, 1982) where cooperation and the adequate use of resources substitute individuality and accumulation of goods and "man is just a thread in the cloth of life and he does not weave it." (Chief Seattle, 1854 - quoted in Sachs, 1986).

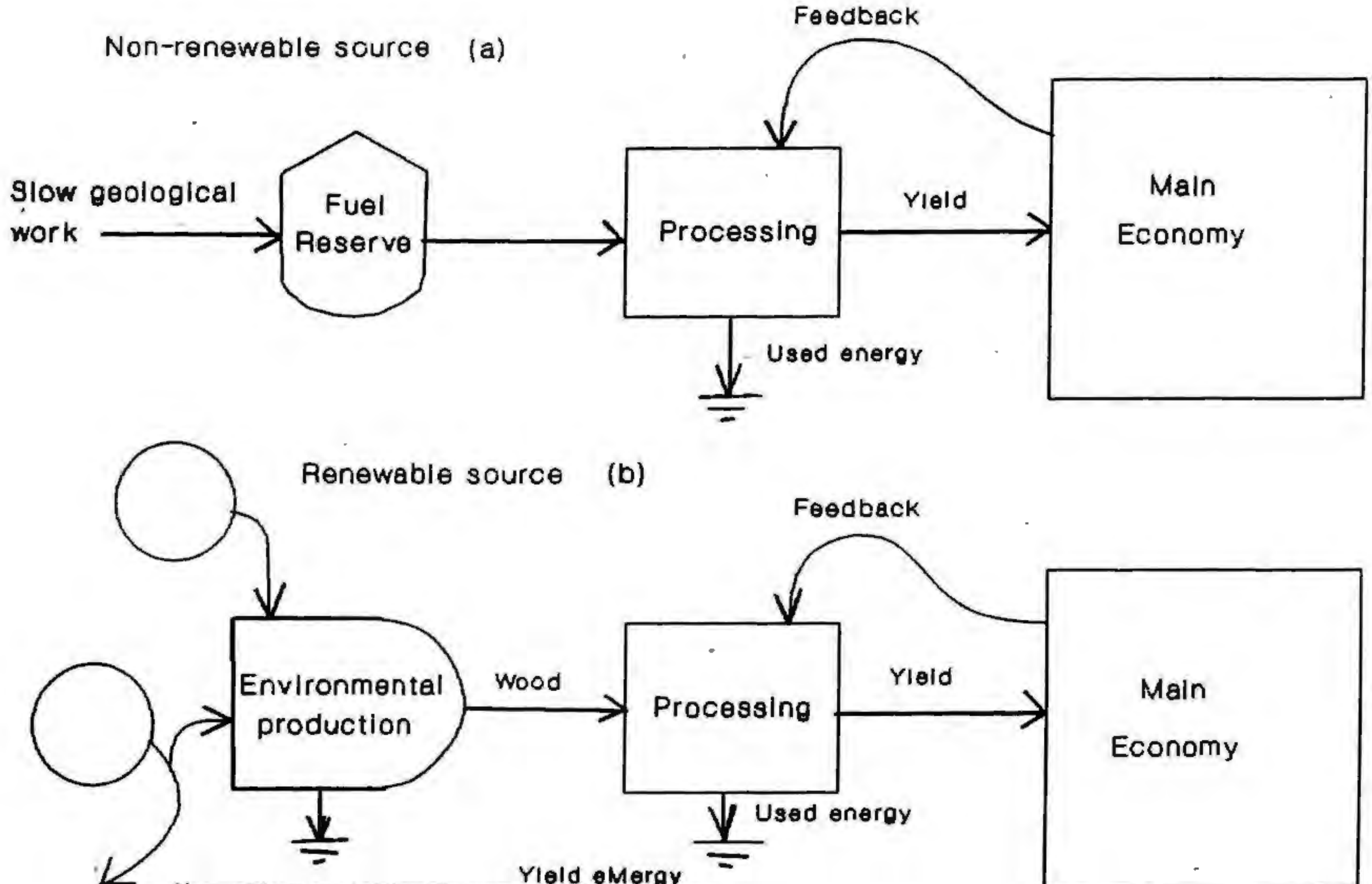
This new conception defines the formulation of policies for development which take into consideration the environmental impacts derived through their application. It also defines administrative efficiency as the optimization between income, more humane working relationships, quality of the finished product and low environmental impact. This is 'ecodevelopment', or "development which is socially desirable, economically viable and ecologically prudent." (Sachs, 1986). The 'quality of life' is now a multidimensional and dynamic phenomenon which includes growth, rationality, spatial allocation and social and environmental impacts (Oliveira, 1993).

Present economic indicators require these new variables for the evaluation and measurement of regional, national and international economic activities.

The eMergetic theory

The eMergetic theory suggests (Odum, 1971, 1983; Odum and Odum, 1983) that the economies of man and nature organize themselves to develop the maximum possible embodied energy. In such a way they are able to be sustainable and prevail over other alternatives. The theoretical basis is the Maximum Power Principle (Lotka, 1922a, 1922b, and 1945, cited in Odum, 1983). For this maximization to take place any economy develops its organization of useful processes which increase its total production through a positive feedback, and thus overcomes limiting factors. The question is not whether processes that are wasteful of their embodied energy do exist today, but whether they will work indefinitely this way in competitive conditions. This goes against the Keynesian theory that any investment of money or resources will bring about economic vitality. Other criteria for survival that have been proposed include: minimal cost, minimum risk, maximum stability, maximum efficiency, maximum production (Westman, 1985), and maximum diversity. In H.T. Odum's approach both the economies themselves as their inner processes are organized and operate to increase their real wealth. They are thus able to prevail according to the principle of the maximization of their embodied energy, which then becomes a measure of true wealth.

To maximize the level of economic well-being of a population, and, at the same time, respecting natural resources, a higher eMergy administration can be chosen. A usage which promotes the production of eMergy coming from environmental sources may mantain the ability of the area to attract more eMergy from external sources. New production processes are promoted as new inputs, externally bought, are brought into the system. The net eMergy of an energy source is its eMergy production less the eMergy used to process it. Primary energy sources can be evaluated using the Net eMergy Yield Ratio, which is the ratio of eMergy production divided by the eMergy used for processing by the economic system (Fig. 2). As the Net eMergy Yield Ratio of the primary sources within an economy increases a greater number of processes can be maintained in the system than just the processing of its own energy. The best policy is then the selection of energy sources with the highest Net eMergy Yield Ratio. This is the case even when these sources must be bought outside of the system.



$$\text{Net eMergy yield ratio} = \frac{\text{Yield eMergy}}{\text{Feedback eMergy}}$$

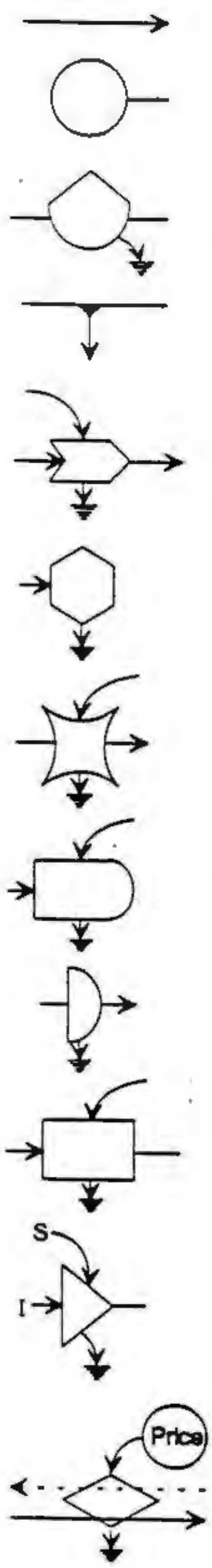
Figure 2 - Net eMergy yield ratio for evaluating a primary energy source. (a) Nonrenewable source; (b) renewable source.

(from Brown, 1992)

Howard Odum started the application of ecological concepts to the analysis of human society in 1971 (Odum, 1971) with his own symbolic language (Fig. 3), by defining the industrial and organizational equivalents of trophic chains by energetic flows of production and consumption. In 1983 (Odum, 1983a) he detailed the question in system analysis terms. Later in the same year (Odum, 1983b) he formed the concept of embodied energy which he applied both to biological systems and to social, industrial and macroeconomic processes (Odum et al., 1986; Odum, 1988).

Calculations in embodied energy, or eMergy, written with an M, used as a common indexing measure, allow one to evaluate and compare resources and benefits for better decision-making at the planning level. At the ecosystem level, all processes of usage, transference, transformation and stocking of energy from the producers down to the consumers may be visualized as energetic flows and quantified in eMergy (joule equivalents of solar eMergy). This is achieved through the conversion of each flow and stock into embodied solar energy as they pass from one state to the other (ex.: leaf biomass to animal biomass; see Fig. 4).

For this process Odum's team developed tables of <u>transformities</u> that were prepared starting from extensive observations and calculations (Odum et al., 1988; Odum and Odum, 1988), and having solar energy as a referencial. The solar energy necessary to obtain one Joule of a specific type of energy is the <u>solar transformity</u> of that type of energy, expressed in Joules of



Energy circuit. A pathway whose flow is proportional to the quantity in the storage or source upstream.

Source. Outside source of energy delivering forces according to a program controlled from outside; a forcing function.

Tank. A compartment of energy storage within the system storing a quantity as the balance of inflows and outflows; a state variable.

Heat sink. Dispersion of potential energy into heat that accompanies all real transformation processes and storages; loss of potential energy from further use by the system.

Interaction. Interactive intersection of two pathways coupled to produce an outflow in proportion to a function of both; control action of one flow on another; limiting factor action; work gate.

Consumer. Unit that transforms energy quality, stores it, and feeds it back autocatalytically to improve inflow.

Switching action. A symbol that indicates one or more switching actions.

Producer. Unit that collects and transforms low-quality energy under control interactions of high-quality flows.

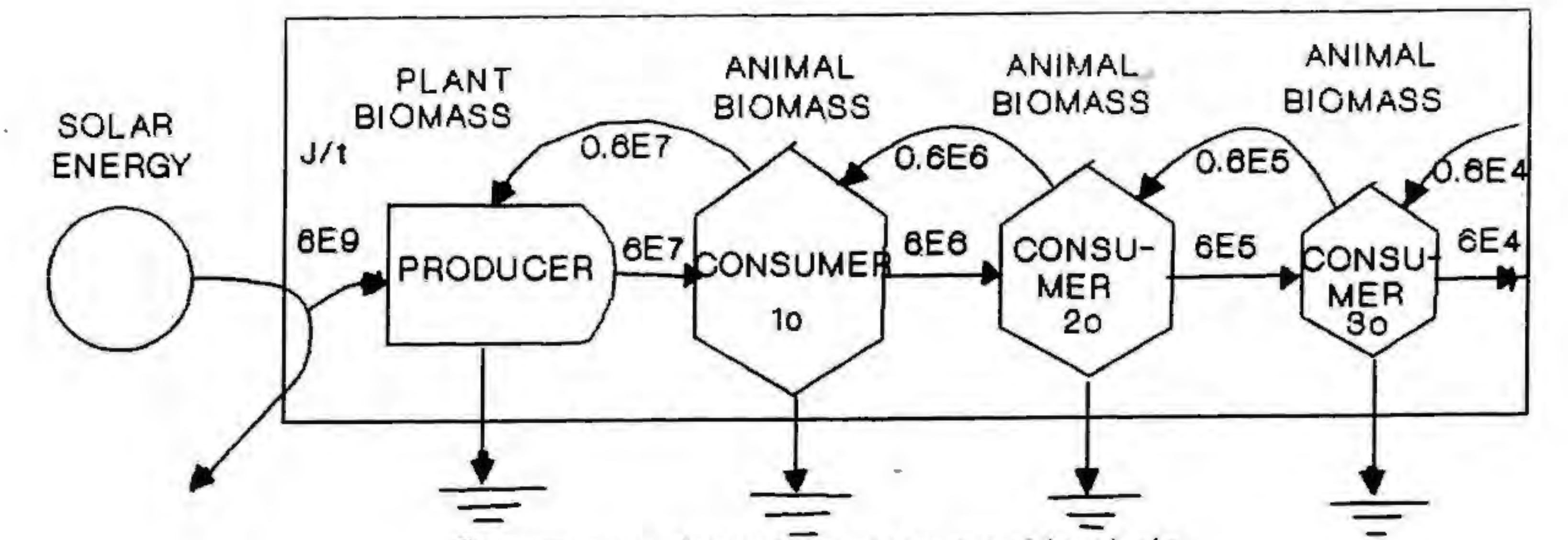
Self-limiting energy receiver. A unit that has a self-limiting output when input drives are high because there is a limiting constant quality of material reacting on a circular pathway within.

Box. Miscellaneous symbol to use for whatever unit or function is labeled.

Constant-gain amplifier. A unit that delivers an output in proportion to the input I but changed by a constant factor as long as the energy source S is sufficient.

Transaction. A unit that indicates a sale of goods or services (solid line) in exchange for payment of money (dashed line). Price is shown as an external source.

Figure 3 Symbols of the energy Language used to represent systems (Odum, 1971, 1983)



Energy transformation along trophic chain.

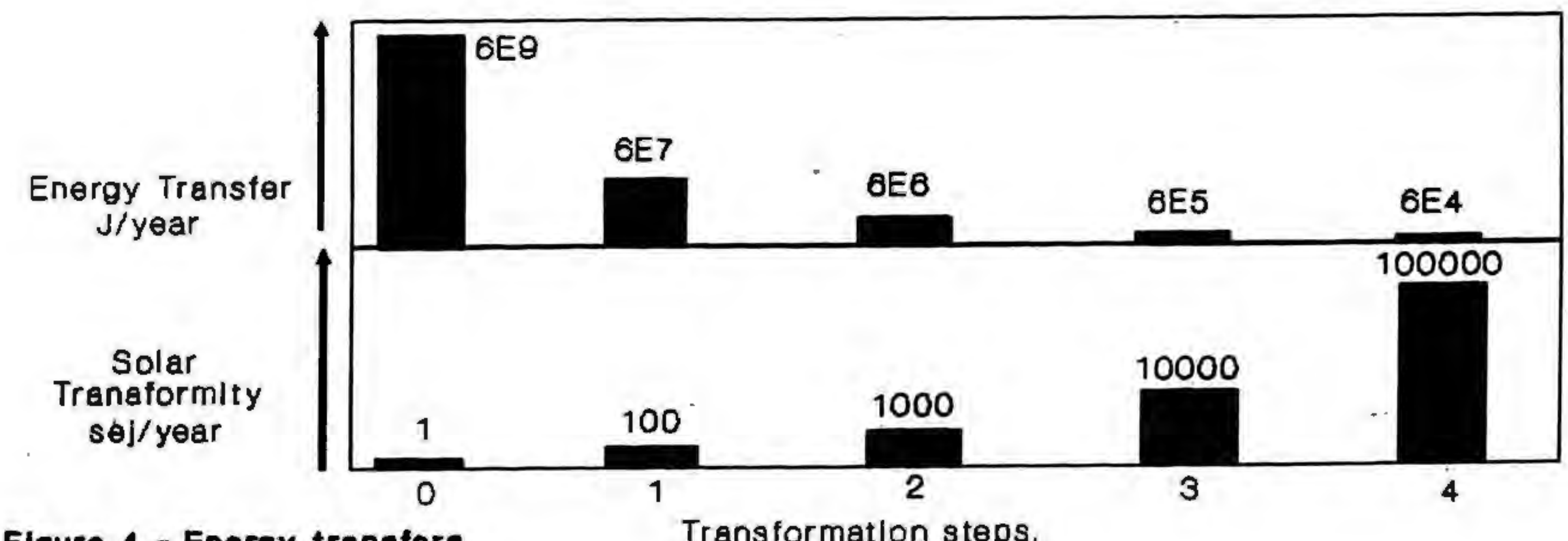


Figure 4 - Energy transfers.

(from Odum, 1983)

Solar eMergy, or embodied solar energy, per Joule (sej/J).

Using the formula:

$$\text{solar transformity of energy type A} = \frac{\text{necessary solar Joules}}{\text{1 Joule of energy type A}}$$

So, if 1,000,000 solar Joules generate 100 Joules of primary consumers, the Solar Transformity of these primary consumers would be:

$$\frac{\text{1,000,000 solar Joules}}{\text{100 Joules of primary consumers}} = \text{10,000 sej/J}$$

Odum considers the energy of primary consumers as being therefore 10,000 times more valuable than the light of the sun. The greater the distances along the trophic chains and the more complex the processes involved, the greater the transformities (see Table 1).

This same reasoning can be applied to processes of industrial transformation or to human activities of a productive or consumer character. In this way the urban system may be evaluated as a whole, having its energetic interactions as a basis. These are then quantified in eMergy terms, both within the various components of the urban system itself, and within the urban system and the environment that supports it.

It is hoped that this type of approach evolves as a tool to improve the decision making process, at a policy level, on the usage of resources and energy and also lead us to better patterns of urban spatial organization.

Table 1. Typical Solar Transformities (solar emjoules per joule)

Item	sej/J
Sunlight	1
Wind kinetic energy	623
Unconsolidated organic matter	4,420
Geopotential energy in dispersed rain	8,888
Chemical energy in dispersed rain	15,423
Geopotential energy in rivers	23,564
Chemical energy in rivers	41,000
Mechanical energy in waves and tides	17,000-29,000
Consolidated fuels	18,000-40,000
Food, greens, grains, staples	24,000-200,000
Protein foods	1,000,000-4,000,000
Human services	80,000-5,000,000
Information	10,000-10,000,000,000,000

Evaluating work through energy usages - an historical framework

In 1842 Robert Meyer, Herman Helmholts and Prescott Joule (Cook, 1976) adapted the concept of energy as a measurement for a determined process from traditional to scientific usage. Karl Marx had used labor as a measure for the realization of useful work (Marx, 1867, cited in Odum, 1983). The mechanical equivalent of heat was developed by Joule (Wood, 1925, cited in Odum, 1983) in terms of heat energy and Maxwell (1877, cited in Odum, 1983) defined the concept of work as an energy transformation. Gibbs applied energy as a measure of total processes by quantifying potential energy and defining it as the ability to drive chemical processes (Gibbs, 1901, cited in Odum, 1983). The necessary energy for changes of states were derived by calculations of energy transformations at infinitely slow rates (Carnot, 1824, cited in Odum, 1983).

The concept of energy as a common denominator to measure all useful work was proposed by various researchers (all cited in Odum, 1983): Boltzmann (1905), Ostwald (1907), Soddy (1912, 1922, 1933), and Cottrell (1955).
Boltzmann (1905) speaking of "mental energetics" was visualizing the concept of embodied energy by measuring the amount of mental energy where the amount of energy developed would always equal the physical energy lost.

In 1922 the maximum power principle was developed by Lotka (1922 a, b) as an extension of natural selection. Linear open-systems of energy transformations were described by Onsager (1931, cited in Odum, 1983), DeGroot (1952), and Prigogine (1955). Juday (1940) and Lindeman (1942) described observed embodied energy in transformation within ecological systems as they attempted an energy analysis (all cited in Odum, 1983).

An energy theory of value, devoid of a basis for energy quality and for a positive utilization of money within an economy, was proposed in the United States in the depression of the 1930s. Its advocates (Scott, 1933; Parrish, 1933, cited in Odum, 1983) were aiming, through a national organization, Technocracy, to propose new economic policies.

In the industrial field, process analysis, of the evaluation of the actual energy flows and their diagramming, was developed in the 1960s (Schmidt and List, 1962, cited in Odum, 1983). It was regarded as a first law analysis. The determination of how much energy input was available for work was sometimes referred to as second law analysis.

In 1971 Odum and Hannon (1973) also proposed energy as a metric of value. Value was also seen either as a function of more effective processes or as a characteristic of human free choice.

Another concept of energy quality in the Carnot ratio. The conversion of heat to work, done at the slowest and most efficient rate possible, is given by the calculation of the Carnot cycle. Where the efficiency of the process of cooling and heating a gas at different pressures can be expressed as the ratio of temperature changes. The ratio of the work done to the heat flow is the efficiency of conversion, which results to be the ratio of temperature change to absolute temperature. Power plants with very high temperatures have high degrees of efficiency. Thus the Carnot ratio is seen as a measure of the energy quality of heat gradients. It measures the ability of energy to be converted into useful work of mechanical quality. It estimates the efficiency at reversible, or stalled condition,. " The efficiency of conversion of heat-gradient source to mechanical energy **at maximum power** is half the Carnot ratio." (Odum, 1983).

Essergy is yet another measure of energy quality (Gibbs, 1873; Evans, 1969, cited in Odum, 1983). It was proposed to evaluate the capacity of energy sources and combinations to do work. Essergy represents the energy available to do work. It is calculated as the sum of the energies, where each is multiplied by the fraction of each energy that can be converted into mechanical work.

" For those energy types of quality lower than that of mechanical energy, it is a measure of theoretical efficiency. It does not consider efficiencies at maximum power. Energy flows of higher quality than mechanical work are not given greater value per calorie. **Exergy** is used for some of the components of the potential energy included in essergy. It is actual energy equivalents in units of mechanical work. Jorgensen and Mejer (1979) use exergy, which is actual energy of one type, to evaluate structure. Embodied exergy may be more appropriate." (Odum, 1983).

In the study of the buffering capacity of an ecosystem to phosphorus loading Jorgensen and Mejer (1977) found that the buffering capacity was proportional to the stored exergy.

It is appropriate here to use Odum's own summary of the concepts of energy transformations, maximum power, system design and transformation ratios, or transformities:

"...useful work was defined as those transformations of energy that contribute to maximum power and survival of the system because of the system design. Energy transformations, by means previously selected under competition for the best possible efficiency commensurate with maximum power, define the inherent thermodynamic energy of one type necessary to generate another type. Ratios of energy of one type necessary to generate another under these conditions are usable for predicting maxima. To compare the relative contribution of energies of different types to potential value, energies are converted to embodied energy equivalents of the same type by use of these transformation ratios.

Embodied energy was defined as a way to measure cumulative action of energies in chains and webs. Embodied energy provides an alternative theory of value, is useful for tracing sources, estimating net energy, determining relative importance of components, and comparing free items that are not covered by money...such energy analysis has been applied to human problems and the energy crisis but is more generally applicable to all systems." (Odum, 1983).

METHODS

The general methodology for eMergy evaluations starts from an overview to progressive details (Odum 1988). Initially, as a means of organizing thinking and relationships among system components, pathways of exchange and resource flow, system diagrams are constructed. Then eMergy tables are derived directly from the diagrams. In the next step eMergy indices that relate eMergy flows of the economy with those of the environment, are calculated. These indices help predict economic viability and carrying capacity. Finally, the results of the eMergy tables and the eMergy indices are used in the suggestions of public policy options by the costs and benefits of proposed developments.

The following definitions are given for key words and concepts:

Energy

Sometimes referred to as the ability to do work. Energy is a property of all things that can be turned into heat and is measured in heat units (BTU, calories, or joules).

eMergy

An expression of all the energy used in the work processes that generate a product or service in units of one type of energy. Solar eMergy of a product is the eMergy of the product expressed in equivalent solar energy required to generate it. Sometimes it is convenient to think of eMergy as energy memory.

eMjoule

The unit of measure of eMergy, "eMergy joule." It is expressed in the units of energy previously used to generate the product; for instance, the solar eMergy of wood is expressed as joules of solar energy that were required to produce the wood.

Maximum eMergy Principle

Systems that prevail are those that take maximum advantage of the eMergy that is available, by: reinforcing productive processes, drawing more resources, and overcoming more limitations through effective system organization. Patterns that maximize eMergy contribute to the most wealth.

Macroeconomic dollar

This is a measure of the money that circulates in an economy as a result of some process. To obtain the value of the macroeconomic dollar of an eMergy flow or storage, the eMergy is multiplied by the ratio of total eMergy ot Gross National Product for the national economy.

Nonrenewable Energy

Energy and material storages like minerals, soils and fossil fuels are consumed at rates that far exceed the rates at which they are produced by geologic processes.

Renewable Energy

Energy flows of the biosphere that are reasonably constant and reocurring and ultimately drive the biological and chemical processes of the earth contributing to geologic processes.

Resident Energy

These are the renewable energies that are characteristic of a region.

Transformity

The ratio obtained by dividing the total eMergy that was used in a process by the energy yielded by the process. Transformities have the dimentions of eMergy/energy. A transformity for a product is calculated by summing all the eMergy inflows to the process and dividing by the energy of the product. Transformities are used to convert energies of different types to eMergy of the same type (see Table 1).

The following is an exposition of the methodology used for eMergy evaluations in general, and, specifically for the timber processing industry of Itacoatiara.

" Ambitious economists elaborated legant mathematical solutions for theoretical problems with li[illegible] or no relevance for public matters." - Washington Post, 20t[illegible] May 1979 (cited in Capra, 1982).

" I believe [illegible] economists [illegible] damage in recent years [illegible] nd to our [illegible] in particular, by p[illegible] an we coul[illegible] er." Milton Frie[illegible] Annal[illegible] Eco[illegible] Association Con[illegible] ice [illegible]

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[illegible] oeconom[illegible] esian i[illegible] igin, stud[illegible] the g[illegible] fun[illegible] o[illegible] ystem as a [illegible] of dynami[illegible] nteracti[illegible] between [illegible] umers. [illegible] global [illegible] heme of capitalis[illegible] conomy [illegible] viewpo[illegible] does not [illegible] nsider th[illegible] government [illegible] e external [illegible] and can presented as [illegible] s (Fonseca [illegible]).

Step 1: Overview System Diagrams

Initially the system under study is put into perspective by drawing a system diagram 'overview' using the energy language symbols illustrated in Figure 3. It combines information about the system from various sources and organizes the efforts in collecting data. The process of diagramming an overview of the system of interest ensures that all driving energies and interactions are included. The diagram includes both the economy and the environment of the system and shows all relevant interactions (Figure 5a).

An aggregated, or simplified, diagram is then drawn retaining the essence of the more complex version (Figure 5b). It is this final, aggregated diagram which is used to construct a table of data requirements for the eMergy evaluation. All pathways crossing the system boundary are evaluated.

Step 2: eMergy Evaluation Tables

Usually the eMergy evaluation of a system is developed at two scales. First, the larger system within which the system of interest is embedded is analyzed and indices are generated that are necessary for evaluation and comparison. Second, the system of interest is compared with other comparable systems, and with the larger system.

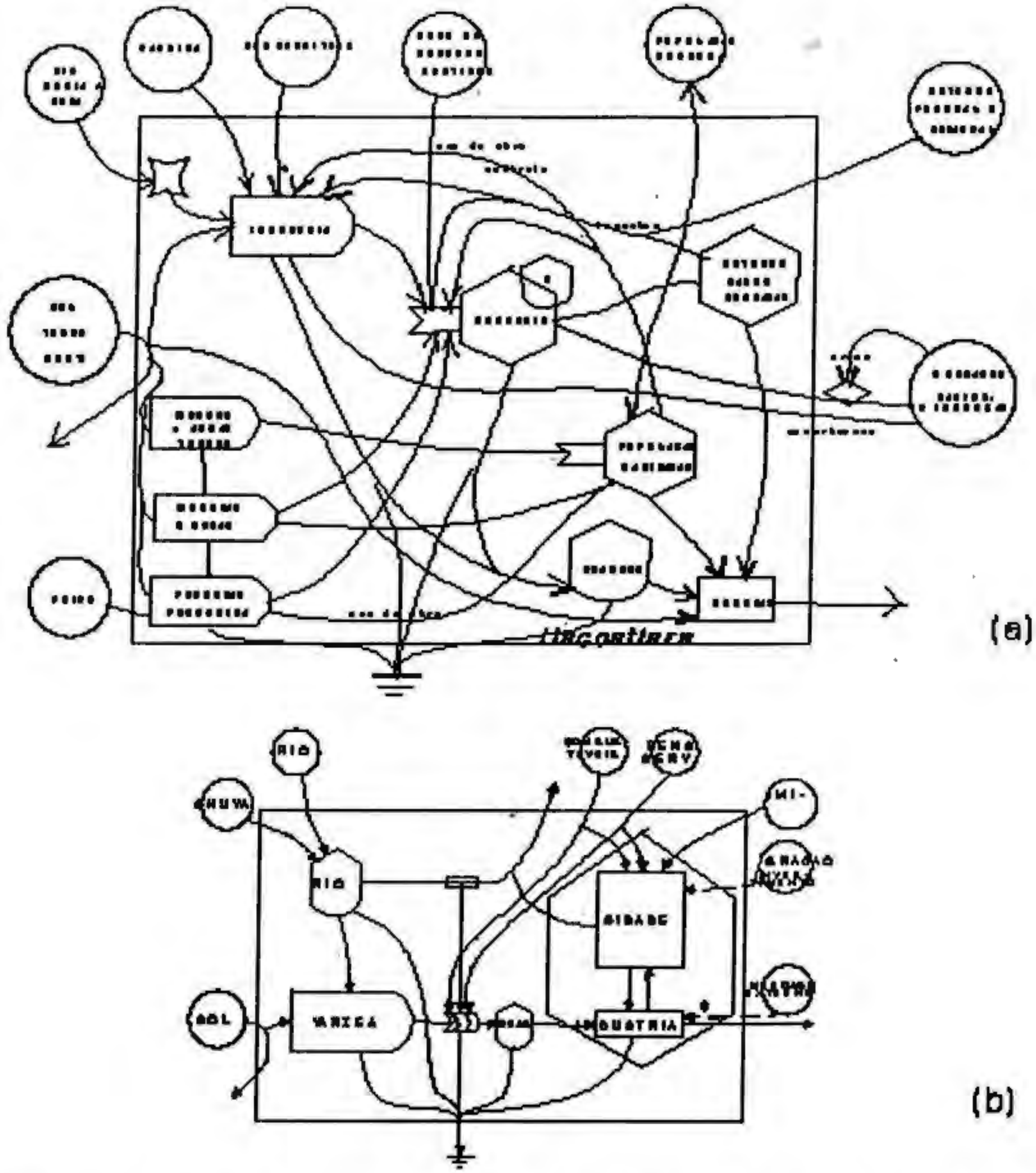


Figure 5 - Overview system diagram(a), aggregated diagram(b)

The evaluation is conducted using an eMergy Evaluation Table which is organized with the following headings:

1	2	3	4	5	6
Note	**Item**	**Raw Units**	**Transformity**	**Solar eMergy**	**Macro-economic $**

Each row in the table is an inflow or outflow pathway in the aggregated diagram of the system of interest. Pathways are evaluated as flows in units per year. An explanation of each column is given here:

Column 1 - The line number and footnote number that contains sources and calculations for the item.
Column 2 - The item name that corresponds to the name of the pathway in the aggregated diagram.
Column 3 - The actual units of the flow, usually evaluated as flux per year. Most often the units are energy (joules/year), but sometimes are given in grams/year.
Column 4 - Transformity of the item, mostly derived from previous studies.
Column 5 - Solar eMergy is the product of the raw units in Column 3 with the transformity in Column 4.
Column 6 - The result of dividing solar eMergy in Column 5 by the eMergy to money ratio (calculated independently) for the economy of the nation within which the system of interest is embedded. (Brown, 1992).

Step 3: Calculation of eMergy Indices

Having completed the eMergy evaluation tables, several indices are calculated from their data to gain perspective and advise in public policy decision-making. Criteria used in judging alternatives differ depending upon whether two systems are being compared or whether a single system is being evaluated for its

contribution to the economy. In the case of two alternative systems being compared, the one which contributes the most eMergy to the public economy and minimizes environmental losses is considered best. When a single system is studied, it is judged to be successful in relation to the economy in which it is embedded by determining how closely its eMergy intensity matches that of the local economy, and whether it minimizes environmental losses.
To accomplish these, two ratios are calculated: eMergy Investment Ratio (IR), and the Environmental Loading Ratio (ELR). Several other indices help in gaining perspective about processes and economies: eMergy Money Ratio, eMergy per Capita, eMergy Density, eMergy Exchange Ratio, Net eMergy Yield Ratio, and Solar Transformity.

eMergy Money Ratio

The ratio of total eMergy flow in the economy of a region or nation to the Gross National Product of the region or nation. The eMergy money ratio is a relative measure of purchasing power when the ratios of two or more nations or regions are compared.

eMergy per Capita

The ratio of total eMergy use in the economy of a region or nation to the total population. EMergy per Capita can be used as a measure of average standard of living of the population.

eMergy Density

The ratio of total eMergy use in the economy of a region or nation to the total area of the region of nation. Renewable and nonrenewable eMergy densities are also calculated separately by dividing the total renewable eMergy by area and the total nonrenewable eMergy by area respectively.

eMergy Exchange Ratio

The ratio of eMergy exchanged in a trade or purchase is a measure of what is received to what is given. The ratio is always expressed relative to one or the other trading partners and is a measure of the relative trade advantage of one partner over the other. Figure 6 shows the relationship and calculation of the eMergy exchange ratio.

Net eMergy Yield Ratio

The ratio of the eMergy yield from a process to the eMergy costs. The ratio is a measure of how much a process contributes to the economy. Primary energy sources have yield ratios ranging from 3/1 to as high as 11/1, thus they greatly contribute to the wealth of the economy. Figure 6 shows the method of calculating the net eMergy yield ratio.

Solar Transformity

This is the ratio of the actual energy in a product or service to the solar eMergy that is required to generate it. The

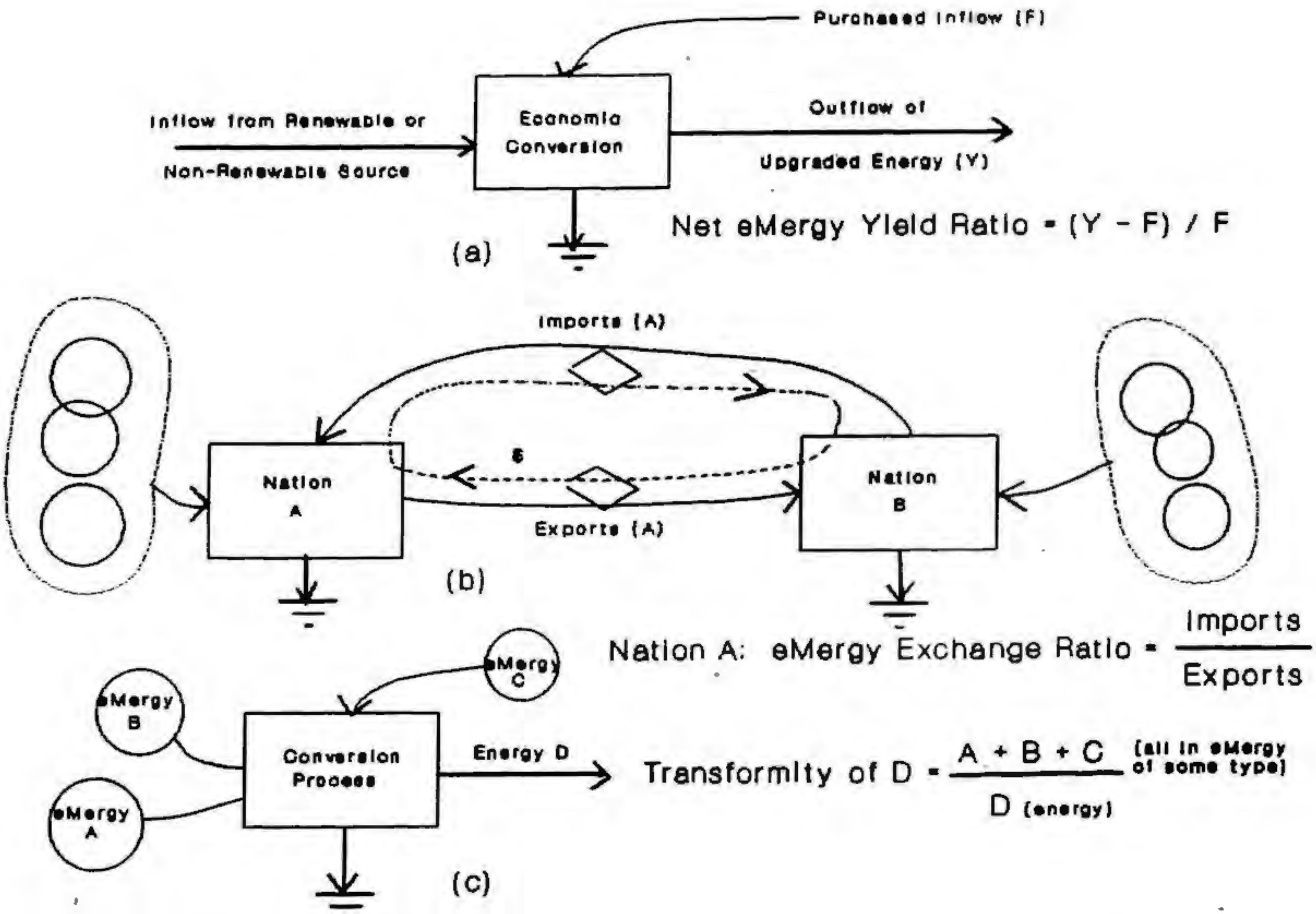


Figure 6 - Diagrams illustrating: (a) calculation of Net eMergy Yield Ratio for an economic conversion where purchased energy is used to upgrade a lower grade resource. (b) calculation of eMergy Exchange Ratio for trade between two nations, and (c) calculation of a Transformity for the flow D taht is a product of the process that requires the input of three different sources of eMergy (A, B and C).

(from Brown, 1992)

transformity is a measure of the 'value' of a service or product. The assumption is that systems operating under the constraints of the maximum eMergy principle generate products that stimulate productive processes at least as much as they cost. Figure 6 shows the method of calculating a transformity.

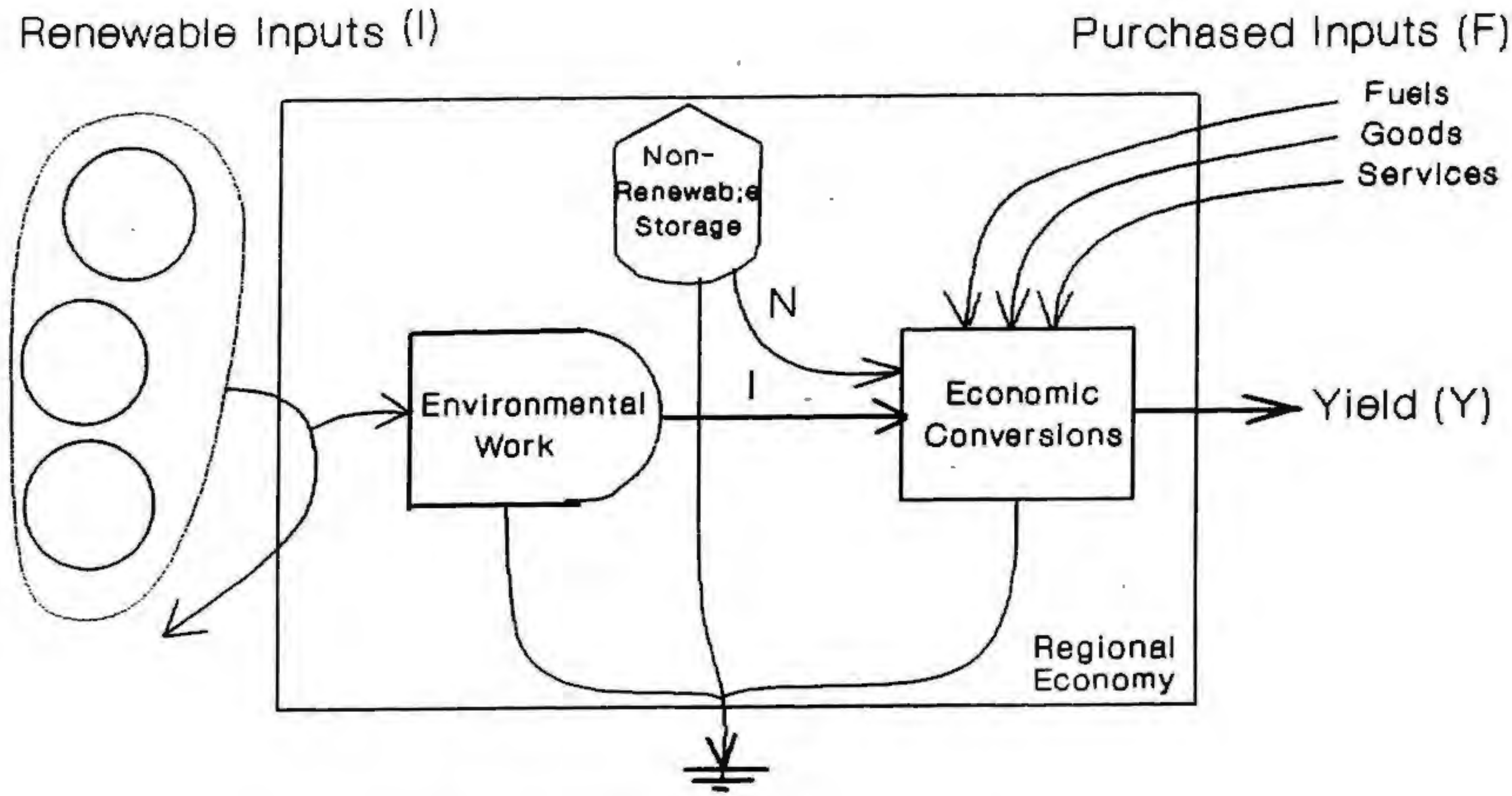
Determining the Intensity of Development and Economic Competitiveness: EmERGY INVESTMENT RATIO

The diagram in Figure 7 illustrates the use of renewable and nonrenewable eMergies in a regional economy. The interaction of nonrenewable eMergies (both purchased from outside [F] and transformed from within [N]) with renewable eMergies (I) is the primary process by which humans interface with their environment.

The Investment Ratio (IR) is the ratio of purchased inputs (F) to all eMergies derived from local sources (the sum of I and N) as follows:

$$\mathbf{IR = F / (I + N)} \qquad (1)$$

It is a ratio of 'invested' eMergy to resident eMergy, and hence its name. The larger the Investment Ratio the greater the intensity of development. Regional or national Investment Ratios are useful for comparison with the Investment Ratio of individual developments of processes. Investment Ratios for nations that have been studied vary from as high as 7/1, for the United States, to as



Investment Ratio of Regional Economy : IR=F/(I+N)
Environmental Loading Ratio of Regional Economy: ELR =(F+N)/I
Yield Ratio of Regional Economy: YR=Y/F

Figure 7 - Regional economy that imports(F) and uses resident renewable inputs(I) and nonrenewable storages(N). Several ratios used for comparisons between systems are given below the diagram. The letters on the pathways refer to flows of eMergy per unit time.

(from Brown, 1992)

low as 0.045/1, for Papua New Guinea (Brown, 1992).

Comparison between regional Investment Ratios and the ratio for proposed or existing developments may be used as an indicator of the intensiveness of the development within the local economy. When the ratios of two developments of similar kind are compared, an indication of their economic competitiveness is derived. The Investment Ratio can also be used to indicate if a process is economical in its utilization of purchased inputs in comparison with other alternative investments within the same economy.

Determining Environmental Impact: **ENVIRONMENTAL LOADING RATIO**

Almost all human production processes involve the interaction of nonrenewable eMergies with the renewable eMergies of the environment. There is always, therefore a pressure on the environment, which can be considered as a load. Figure 7 shows environmental loading as a result of the interaction of purchased eMergy (F) and nonrenewable storages of eMergy (N) from within the system. The renewable eMergy pathway (I) is coming through the agency of Environmental Work.

Determining Carrying Capacity for Economic Investments

Once the ELR for a region is known and the total annual nonrenewable eMergy use by a development is determined, the area of land necessary to balance the development can be calculated using the average annual flux of renewable eMergy per year per unit area of landscape, the renewable eMergy Density. Renewable energy density is derived from the analysis of the regional or national economy. To determine the area of support necessary for a proposed development, and thus the carrying capacity (i.e., the area of landscape required for the development), the environmental loading ratio for the region is calculated and then a simple equivalent proportion is constructed:

$$\text{ELR (region)} = \text{ELR (development)} \qquad (6)$$

where: ELR (region) = known

$$\text{ELR (development)}=[Fi + (Fm - kFM)+Ns]/(Is + kFm)$$

and the equation is solved as follows:

$$(Is + kFm) = [Fi + (Fm - kFm) + Ns] \,/\, \text{ELR (region)} \qquad (7)$$

Once the quantity is known, the area of landscape required to balance the proposed development is calculated as follows:

$$\text{Support Area} = (Is + kFm)/\text{renewable eMergy density} \qquad (8)$$

The investment ratio of the sector (IRs) is calculated in a similar manner acoounting for all sources of renewable and purchased eMergy as follows:

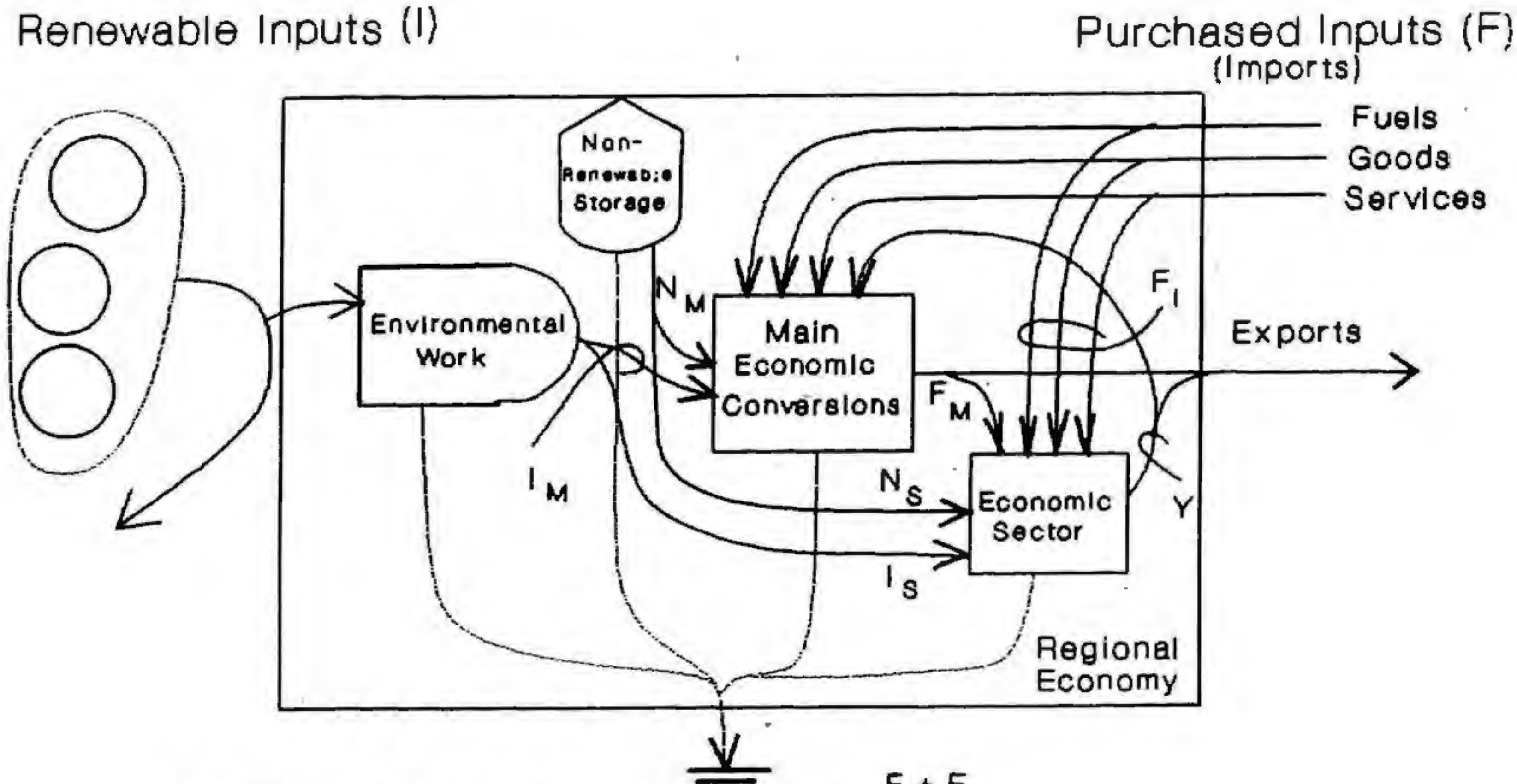
$$IRs = (Fm + Fi)/(Is + Ns) \qquad (4)$$

The regional ELR is calculated as the ratio of nonrenewable (F + Nm) to renewable eMergy (Im). The calculation for ELR for the economic sector has, however, to take into account the portion of Fm that comes from Im, since that area of environment is not adding to the 'load' on the envirnonment of the sector but is part of the environmental support for the sector. The ELR for the sector is thus calculated by subtracting the portion of Fm that is from Im. This is done by first calculating the total eMergy budget of the main economy (Total eMergy = Fm + Fi + Nm + Ns + Im + Is) and then dividing to determine the percent of the total that is derived from Im (referred to as k in Figure 8). Then the ELR for the sector is determined as follows (Brown, 1992):

$$ELRs = [Fi + (Fm - k\ Fm) + Ns] / (Is + k\ Fm) \qquad (5)$$

where:

k = percent of total eMergy budget that is from I (see Figure 8).



Investment Ratio for Economic Sector: $IR = \dfrac{F_I + F_M}{I_S + N_S}$

Environmental Loading Ratio for Economic Sector: $ELR = \dfrac{F_I + (F_M - KF_M) + N_S}{I_S + KF_M}$

where K = percent of F_M that is from I_M

Yield Ratio for Economic Sector: $YR = \dfrac{Y}{F_M + F_I}$

Figure 8 - Regional economy with energy flows from external sources and within the economy. One sector of the economy is shown separated from the main economy in the lower right. The sector receives energy from imports(FI), from main economy (Fm), from nonrenewable storages(Ns), from the environment(Is)

(from Brown, 1992)

The Environmental Loading Ratio (ELR) is the ratio of nonrenewable eMergy (N + F) to renewable eMergy (I), and is an index of environmental loading:

$$\mathbf{ELR = (N + F)/ I} \tag{2}$$

Low Environmental Loading Ratios reflect relatively small environmental loading, high ELRs suggest greater loading. This ratio reflects the potential stress or strain on the environment represented by a proposed development when compared to the same ratio for the region, and can be used to calculate carrying capacity.

Evaluating Regional and Local IRs and ELRs

Figure 8 shows a simplified diagram of a regional economy and a sector of the economy. The sector uses renewable eMergy (Is) and purchased eMergy from both the local (Fm) and the world economy (Fi). The sector is part of the regional economy but is shown separately to clarify the comparison between it and the region within which it is embedded. The investment ratio in the regional economy is derived using the ratio of purchased eMergy (F) to resident eMergy inputs (Im + Nm) as follows:

$$\mathbf{IRm = F / (Im + Nm)} \tag{3}$$

Data collection in Itacoatiara and Manaus

The majority of the data were collected during 1991 and 1992, in 1993 some cross-checking occurred principally with individuals involved in the plywood industry, both in Itacoatiara and Manaus. A structured interview form was prepared for contacts with Itacoatiara's industry, but was not used with plywood mill officials (Appendix A), although it formed the basis for many site interviews. Workers, from highly skilled ones in managerial positions to labor hands were interviewed during 1991 and 1992. Some timber entrepreneurs in Itacoatiara and some in Manaus, that had been working in Itacoatiara, were interviewed. Various government agencies were contacted. Some had readily available data, others provided them after research either by their staff or by the author. Here is a list of the main government institutions that helped with the collection of data and information:

CEAM - Amazonas State Electricity Commission
CODEAMA - Amazonas State Government Rural Research and Statistics Commission.
EMATER - Federal Government Agency for Rural and Agricultural Development
IBGE-AM - Brazilian Institute of Geography and Statistics, Amazonas Chapter.
ICOTI - Amazonas State Government Institute for Rural Municipalities.
INPA - National Institute for Amazon Research.
ITACOATIARA - Municipal Public Works Department and Municipal Finance Department.
SEFAZ - State Taxation Department.
Sub-Secretariat for Amazonas State Finances.

Appendix B shows the source of the data, the basis on which data were generated and the degree of confidence that can be assumed

RESULTS

Overview of Brazil

Inputs of sun, rain, rivers, and imported goods and services are shown in the aggregated diagram for Brazil (Figure 9). Forests and agriculture represent the country's production while industry and the commercial network use natural resources. The urban population is supported by these resources and manages them at the same time. The annual flow of energy in Brazil and its eMergy value are presented in Table 2. The single most important renewable resource is the chemical potential of rain. Important indigenous resources are firewood and lumber. Important imported eMergies include oil, natural gas, coal, potash, phosphates, nitrogen. Foreign services and imported products represent very high eMergies because of human services involved in their production. Agricultural products, iron ore, and some minerals are the most important exports.

Summary diagrams of eMergy flows that support Brazil's economy are given in Figure 9. The top diagram (a) is an aggregate of all the eMergy inputs, which include: imported fuels and goods (F and G), imported services (P2I), renewable resources (R), nonrenewable resources derived from within the country (No, N1), and N2). Exports from the economy are made up of three flows: direct export

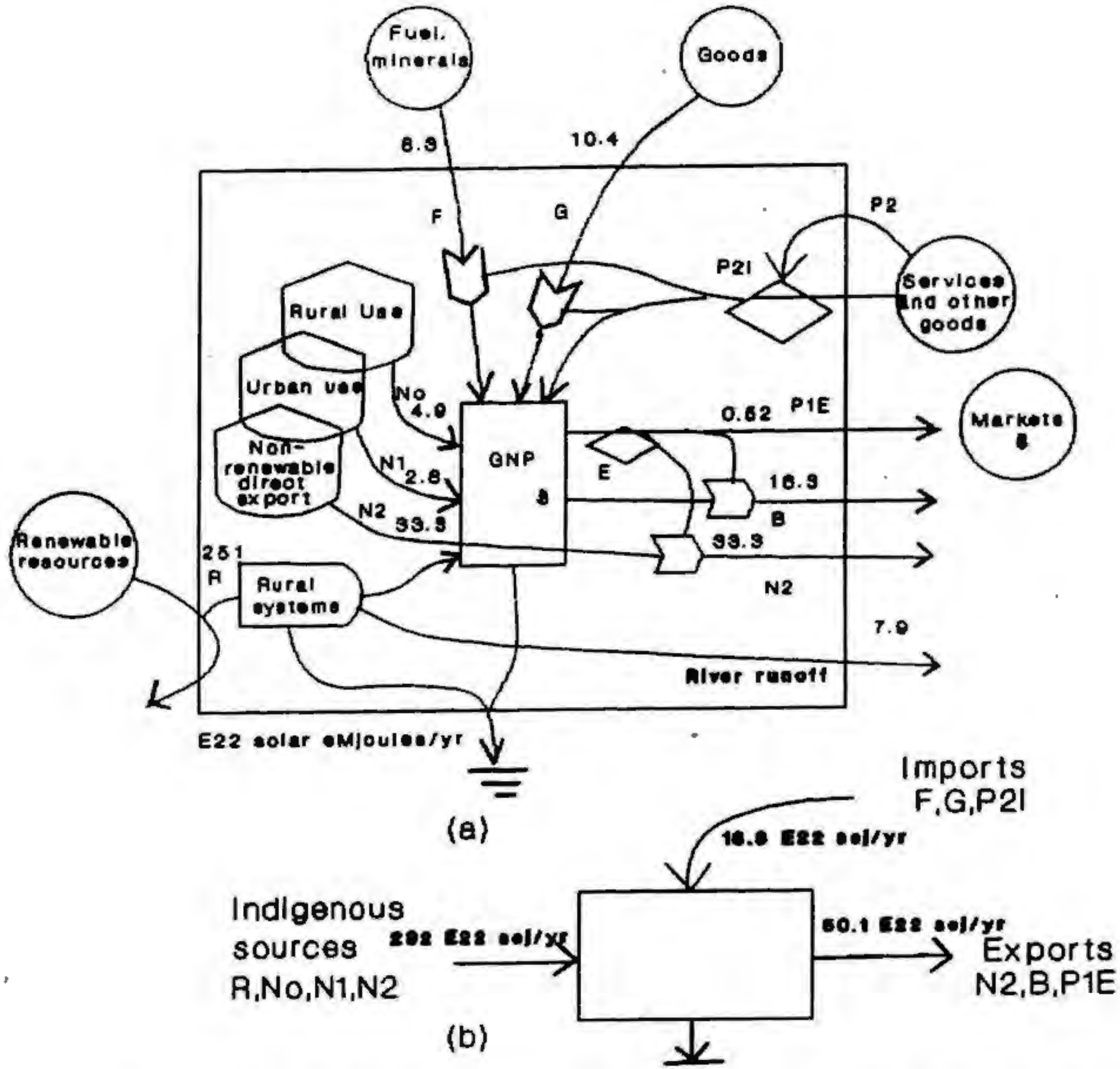


Figure 9 - Brazil's eMergy diagram (flows in eMergy units)

Table 2

EMERGY EVALUATION OF BRAZIL (1989 statistical data)

Note	Item	units/yr		Transformity sej/unit	Solar eMergy E21 sej/yr
RENEWABLE RESOURCES					
1	sunlight	J	4.60E+22	1.00E+00	46.00
2	wind	J	1.00E+00	1.50E+03	0.00
3	rain	J	6.76E+19	1.50E+04	1014.00
4	river inf low	J	1.34E+19	4.10E+04	549.40
5	net earth inflow	J	5.50E+14	1.71E+09	940.50
6	tide	J	2.37E+17	2.35E+04	5.57
7	river run	J	1.26E+18	6.25E+04	78.75
	SUM of free inputs (sun, wind omitted)- runoff				2509.47
INDIGENOUS SOURCES					
8	firewood	Tpe	1.41E+18	3.50E+04	49.35
9	lumber	J	8.04E+17	3.50E+04	28.14
	SUM of indigenous sources				77.49
NON-RENEWABLE DIRECT EXPORT					
10	food	J	2.18E+17	4.50E+05	98.10
11	metals	T	1.40E+07	4.65E+15	65.10
12	minerals	T	1.26E+08	2.64E+15	332.64
	SUM of non-renewable direct exports				495.84
PURCHASED INPUTS					
13	oil,n.gas ,coal	J	1.56E+18	5.30E+04	82.68
14	goods,min erals	J	6.96E+14	6.00E+07	41.76
15	potash	J	1.76E+15	3.14E+07	55.26
16	phosphate	J	1.53E+14	1.01E+07	1.55
17	nitrogen	J	3.26E+15	1.75E+06	5.71
18	services	$	4.31E+08	3.60E+12	1.55
	SUM of purchased imports				188.51
EXPORTED SERVICES					
19	services	$	8.28E+08	6.08E+12	5.03

Total eMergy used in Brazil	2274.59
solar eMergy joules/dollar ratio for Brazil (1989)= (incoming flows - exports)/GNP	
(GNP-Brazil 1989: $ 374.142 E9) sej/$-Brazil=	6.08E+12
(1991 World Bank Report) Against 8.9 E12 sej/$ (1979)	8.91E+12

NOTES

1 and 2 Solar and wind energies were not included as they represent small relative values.

3 Rain, chemical potential (8.51 E12 m^2)(1.5589 m/y)(5 J/g)

(1 E6 g/m^3) = 6.67 E19 J/y
Rain: Mean of annual rainfall of 27 capital cities
Table 2 (continued)

1589 mm/y (Fundacao Instituto Brasileiro de Geografia e Est. 1980). Rain, Geopotential - 4.66 E19

4 River Inflow - 1.34 E19 J/yr
5 Net earth inflow 94.1 E22 sej/yr.
6 Tide 2.37E17 J/yr
7 River runoff 1.26 E18 J/yr
8 Firewood 1.41 E18 Tpe/yr
9 Lumber 6.04 E17 J/yr
10 Food - (13 E6 T)(4 Kcal/g)(41186 J/Kcal) = 2.18E+17
Emergy in Food = 2.17 E17 * 4.5 E5 = 9.81E+22
11 Metals, Steel- (14 E6 T)(4.65 E15 sej/T) = 6.51E+22
12-19 Data from IBGE (Instituto Brasileiro de Geografia e Estatística) Anuário Estatístico do Brasil - 1989.

of non-renewable resources (N2), exports of economic products (E) and exports of services derived from the dollar income from exported goods (P1E). The GNP (X) is of $ 374.14 E9. The bottom diagram (b) summarizes Brazil's economy by summing eMergy flows from indigenous sources (R + No + N1 + N2), imports (F + G + P2I), and exports (N2 + E + P1E). P1E is defined as eMergy-to-dollar ratio for Brazil (P1) multiplied by total exports (E). P2I is defined as the world eMergy-to-dollar ratio (P2 = 3.8 E12 sej/$) multiplied by imports (F + G = I).

Table 3 presents the overall indices of the eMergy overview of Brazil. Brazil's eMergy money ratio (6.08 E + 12 Sej/$) is almost double the world average (3.8 E + 12 Sej/$). Almost all, 93 %, of the eMergy basis for Brazil's economy comes from within the country (line 7), only 7 % is imported (line 12). Of the total eMergy of the economy 18% is exported (line 10). Almost all of the eMergy use, 92 % (line 14), is locally renewable. Brazil has a net eMergy deficit from trade (312 E21 sej/yr, line 8). The ratio of imported eMergy to exported eMergy is 0.38/1 (line 9). Only 0.06 % of the country's eMergy budget comes from imported services (line 13). The <u>renewable eMergy carrying capacity</u> at present living standard (line 17) is a measure of long-term, sustainable, carrying capacity for humans in Brazil's landscape. The percent of total eMergy from rural sources (90%) is multiplied by the present population (147.3 million people - 1989 figure). It is a measure of the number of people that could be supported by renewable

Table 3. Overview Indices of Brazil, 1989.

No.	Description	Expression	Quantity
1	Renewable eMergy flow	R	2509.47 E21 sej/yr
2	Flow from indigenous nonrenewable reserves	N	410.13 E21 sej/yr
3	Flow of imported eMergy	F + G + P2I	188.51 E21 sej/yr
4	Total eMergy Inflows	R + N + F + G + P2I	3108.11 E21 sej/yr
5	Total eMergy used, U	No + N1 + R + F + G + P2I	2274.59 E21 sej/yr
6	Total exported eMergy	N2 + B + P1E	501.05 E21 sej/yr
7	Fraction of eMergy use derived from home sources	(No + N1 + R) / U	93.21%
8	Imports minus exports	(F + G + P2I)-(N2 + B + P1E	-312.54 E21 sej/yr
9	Ratio of imports to exports	(F + G + P2I)/(N2 + B + P1E	0.38
10	Fraction of eMergy that is exported	(N2 + B + P1E) / U	18.05%
11	Fraction used, locally renewable	R / U	90.42%
12	Fraction of eMergy use purchased (imports)	(F + G + P2I) / U	6.79%
13	Fraction imported service	P2I / U	0.06%
14	Fraction of use that is free	(R + No) / U	92.19%
15	eMergy density	U / area	3.26E+11 sej/m²
16	eMergy per capita	U / (population)	3.402E+15 sej/person
17	Renewable carrying capacity at present living standard	(R / U)(population)	1.33E+08 people
18	Developed carrying capacity at present living standard	8R / (U / population)	1.07E+09 people
19	eMergy money ratio	P1 = U / GNP	6.079E+12 sej/$
20	Fuel use per person	fuel / population	5.613E+14 sej/person
21	Environmental Loading Ratio	(No + N1 + F + G + P2I) / R	0.11
22	Investment Ratio	F / (R + N)	0.064 0.064/1

sources alone, were they to maintain their 1989 living standard. The renewable carrying capacity of Brazil is 133 million people or about 90 % of 1989's population. Line 18 represents the carrying capacity assuming development of Brazil's economy to that which is characteristic of developed nations like the United States, but using Brazil's present standard of living. The developed carrying capacity is calculated by multiplying renewable eMergy flow (R) by 8.0 (the ratio of concentrated to renewable eMergy in developed economies, Brown and McClanahan, 1992) and dividing by the current eMergy use per capita (3.402 E15 sej/person; line 16). The developed carrying capacity is 1070 million people, but assumes that world energy supplies are of sufficient size that this may be accomplished, and that present living standards would be maintained in the future. The bigger the Investment Ratio the greater the intensity of development. Brazil's very low investment ratio of 0.064/1 (Table 3 - line 22, and table 4) is very close to Papua New Guinea (0.04/1, Table 4). Brazil's ratio is around 1/5th of Mexico (0.3/1, Table 4) showing a relatively low intensity of development.

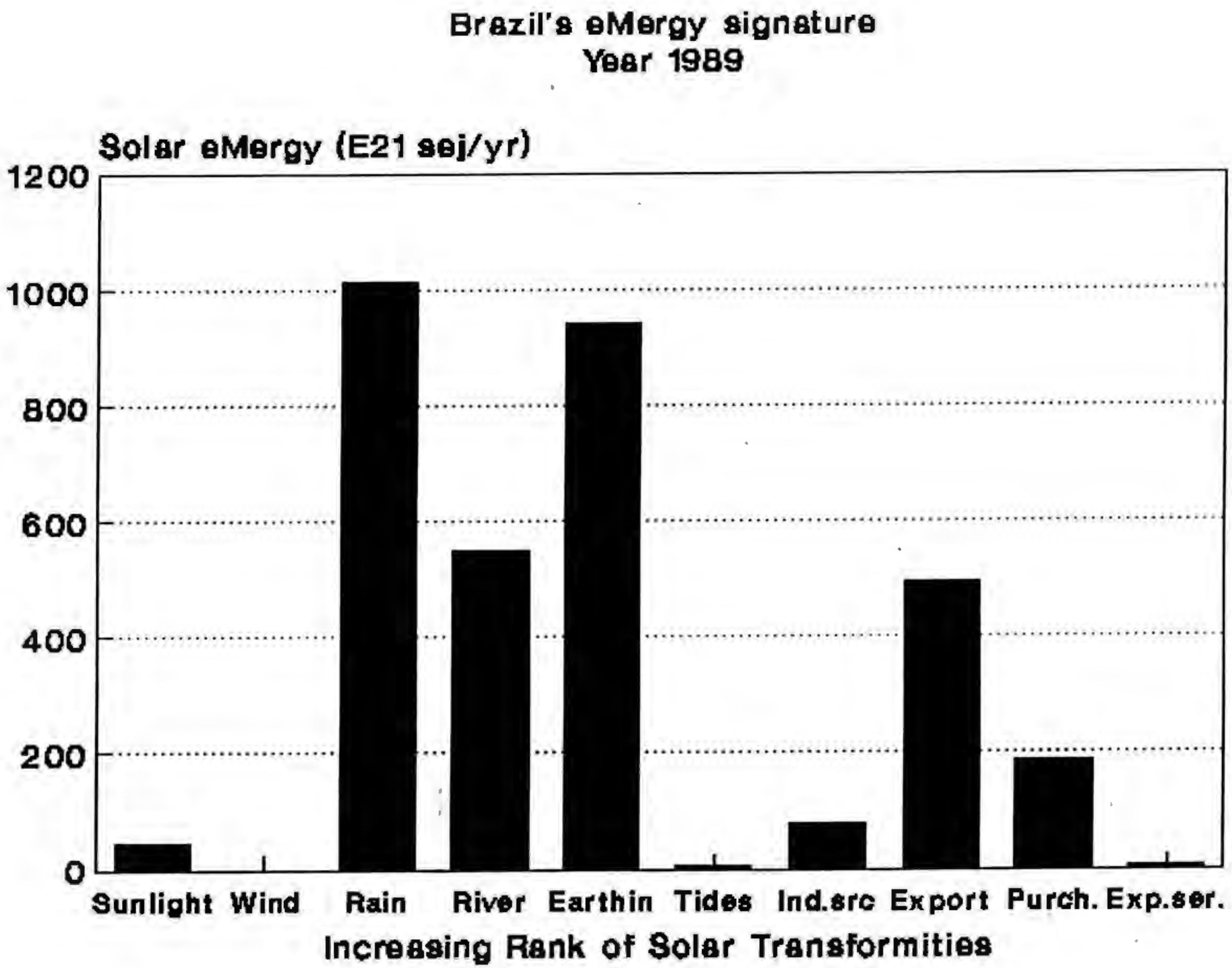


Figure 10 - Brazil's eMergy signature

Table 4. Comparative national eMergy indices for Papua New Guinea, Brazil, Mexico, and the United States

INDEX	PNG	BRAZIL	MEXICO	USA
Total eMergy Use (E20 sej/yr)	1216	27755	4818	78600
GNP (E9 US $/yr)	2.5	374	185	4880
Area (E10 m^2)	46.2	851	196	940
Population (E6 people)	3.5	147.3	81.1	244
eMergy/ money ratio (E12 sej/$)	4.8	6.08	2.6	1.6
eMergy density (E11 sej/m^2)	2.6	3.26	2	8.4
eMergy per capita (E15 sej/person*yr)	37.7	3.4	5.9	32.2
World eMergy exchange ratio #	0.08	0.625	1.5	2.4
Investment ratio	0.04	0.064	0.3	0.3
Environmental loading ratio	0.16	0.106	1.9	8.8

eMergy trade advantage of country based on ratio of world eMergy/money ratio (3.8 E12 sej/$) to the eMergy/money ratio for the country.

Rio Madeira Basin and Itacoatiara

The Central Amazon town of Itacoatiara, 284 km east of the capital city of Manaus, with a population of around 60,000, is strategically placed at the confluence of the Amazon and the Madeira rivers (Figure 11). Several plywood and veneer firms located their factories in the town due to easy access to water borne timber. Plywood industries in Itacoatiara were responsible in 1989 for 21% of plywood and veneer production of the state of Amazonas, which totalled for that year around 125,000 cubic meters (Mota, personal communication). 10 % of all Plywood industries in the state are considered of large size, this means a production of 1000 to 2000 cubic meters per month. All of Itacoatiara's industries fall within this category (Hummel et al. 1993).

More than 80% of the existing timber species in the region can be used for plywood panels, although they have been restricted to species that have good floating capacity, or whose fresh density is lower than water. During the late 1970s through the 1980s plywood and veneer firms relied almost exclusively on timber from the Rio Madeira floodlands (" Várzeas "). Logs were felled during low water season and water borne during the high water one. As timber was increasingly difficult to get from this area since 1989, due both to scarcity and to irregular flood levels, many areas outside the Madeira River basin started to be used for timber extraction

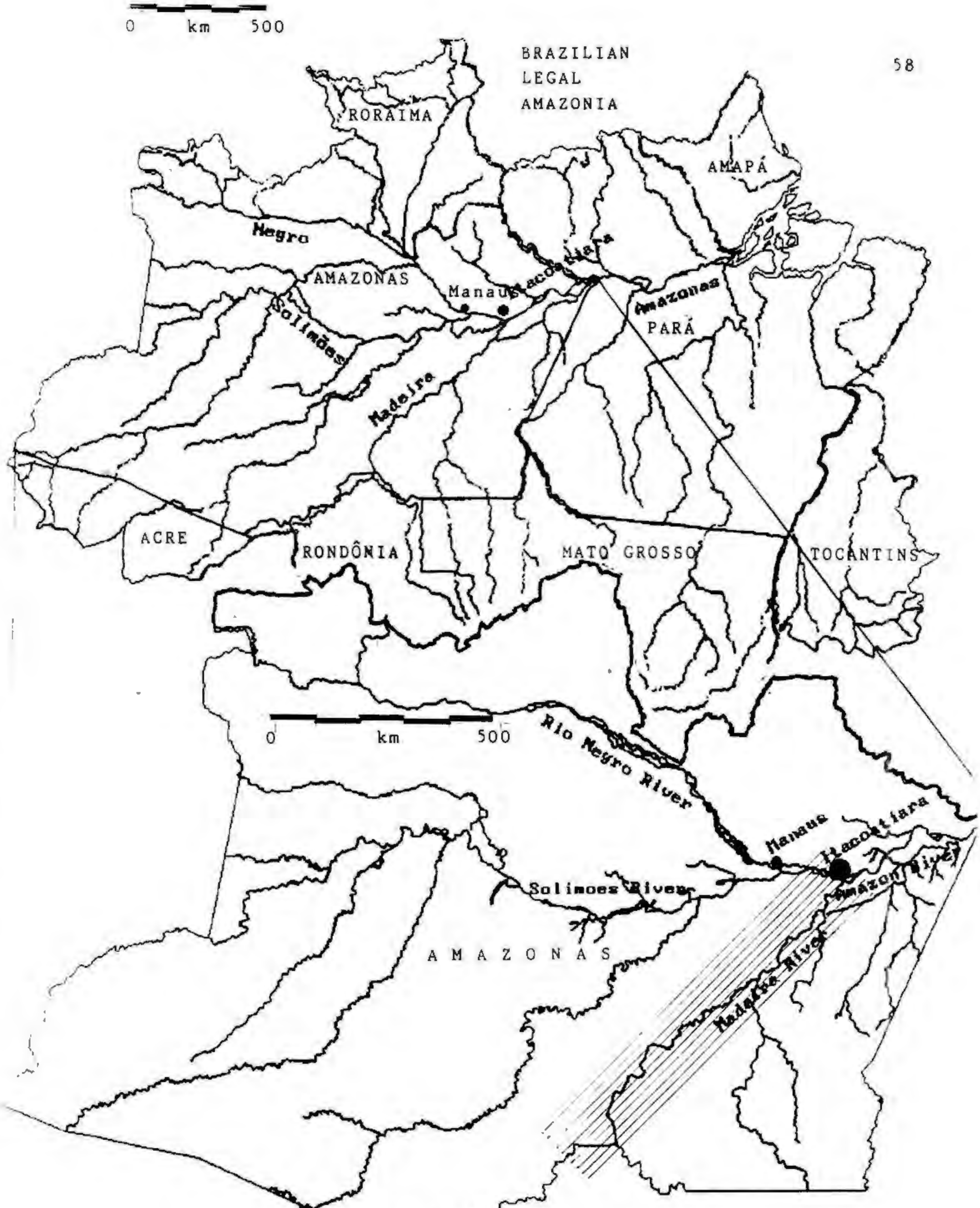
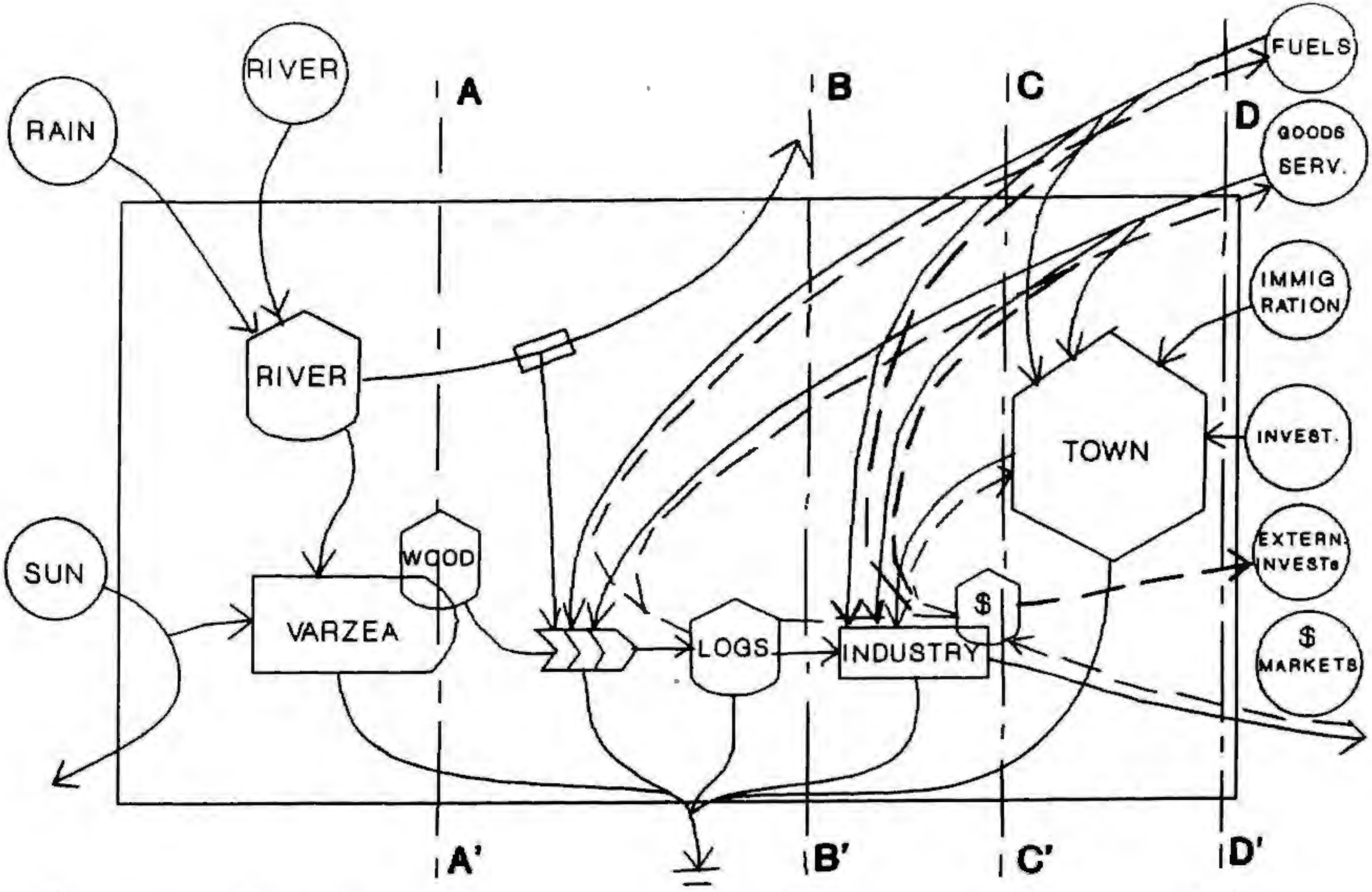


Figure 11 - Itacoatiara and the Rio Madeira Basin within the Amazon State (Amazonas).

from these firms. The present trend is to use heavy machinery such as skidders and bulldozers combined with large barges as against the original system of water borne rafts composed by thousands (3000 to 4000 average) of logs collected exclusively by hand labor. The reason is that most of the available timber in the floodlands has already been harvested and demand cannot wait for irregular harvesting by the local population using the traditional method. Also, the unpredictability of flood levels was a major factor in this change.

I evaluated forest flood area for the Rio Madeira Basin from the RADAMBRAZIL 1972-73 maps, starting 30 kilometers downstream from Porto Velho, to be of 7370 km^2. Based on site interviews and other sources I estimated the yearly timber volume arriving in Itacoatiara from the Rio Madeira, from 1985 to 1989, at around 100,000 cubic meters. The yearly demand in Itacoatiara has been around 250,000 cubic meters, which has been obtained from many different areas within the Amazon Basin. The overview system diagram in Figure 12 represents an aggregation of the main components, sources and pathways, with specific emphasis on the flow of logs and the plywood production process, within the boundaries of the Madeira's varzea area and the town of Itacoatiara.

Sun, rain and river energies combine with the geological base and genetic resources to produce wood biomass in the varzea. The



	A'	B'	C'	D'
Net eMergy Yield Ratio (Y/F)	-	2.56	1.66	1.004
eMergy Investment Ratio (F/I)	-	0.64	1.51	364.37
Transformity (sej/yr)	1.7 E4	2.79 E4	2.39 E5	3.9 E5

Figure 12 - Diagram of eMergy transfers from timber to plywood panels

river also provides kinetic energy to facilitate log transport downstream, interacting with the two human-provided sources of fuels and goods and services - in the form of boats, equipments, harvesting and transportation services. Logs, assembled through a network of local families and middle-men, are stocked by Itacoatiara's industries and, using the town's labor force, processed into finished products to markets. Broken lines define money flows, initiating from markets and eventually reaching the town through labor payments. Immigration and investments partly define the town's growth.

To evaluate the energies, their interactions and the trasformations involved in each process, I defined four section lines: AA', BB', CC' and DD', each corresponding to a significant step in the process of plywood production and each quantified in a separate table (Tables 5 to 8).

Following energy transfers at different steps of plywood production

In Table 5, the first section (AA'), evaluates natural energy sources and their contributions to the production of wood biomass in the varzea. There is no feedback from humans. Sunlight, rain and river energies contribute, but the determining factor is the rain. Rain water goes to the river and is used by the trees according to the varzea forest's evapotranspiration rate of

Table 5
EMERGY EVALUATION OF THE VARZEA SYSTEM

SECTION LINE AA

NoteItem			Units/yr	Transformity sej/unit	Solar eMergy E19 sej/yr
ENVIRONMENT					
1 Sunlight	J	3.46E+19	J	1.00E+00	3.46
2 Rain	J	5.74E+16	J	1.50E+04	86.17
3 River cont.	J	6.73E+16	J	1.50E+04	100.88
Sum of Environmental Emergy Contribution					100.88
FEEDBACK					
No feedback from humans					
PRODUCTION PROCESS					
4 Forest Product.	J	5.92E+16	J	1.70E+04	100.70
Transformity of Varzea Forest					
Total Emergy used/energy = 1.01E+21/5.92E+16 =					1.70E+04

NOTES:

1 Sun's contribution is accounted for in Rain's:
Area*albedo*energy in Joules/yr =
(7370 km2)(E6 m/km2)(0.80)(140 Kcal/cm2/yr)(186 J/Kcal)
(1E4 cm2/m2) = 3.46E+19 J/yr

2 Varzea area is considered in calculations. Rain goes to river then to trees.
Rain Chemical Potential = (varzea area)(precipitation ave.)(G)
(7370 km2)(E6 m/k 2)(1.5589 m/yr)(5 J/g)(1E6 g/m3)= 5.74E+16 J/yr

3 River contribution to varzea -see evapotranspiration for varzea values (Salati, 1 84; Marques, 1986/87). The energy available to varzea is related to evapotranspiration:
(5000 g/m2/day)(365 days/yr)(7370 km)(E6 m/km2)(5J/g) 6.73E+16 J/yr

4 Forest Production - Biomass production/year in Joules
(480 g/m2/yr)(4 Kcal/g)(4186 J/Kcal)(7370 km2)(E6 m/km2)=
5.92E+16 J/yr. Biomass production figure (local estimates-Higuchi, personal comm.)

5000 g/m²/day (Salati, 1984; Marques, 1986/87). Thus the river contribution is the one accounted for, line 3, amounting to 100.88 E19 sej/yr. This amount of embodied energy, or eMergy, is responsible for the production of 480 g/m²/yr of varzea forest above ground biomass (Higuchi, personal communication), which totals 5.92 E16 Joules per year for the area studied.

Dividing the total eMergy used by the energy produced within a year one can calculate the transformity of varzea forest biomass. This is 1.7 E4 sej/yr.

It is interesting to notice that the system is in balance as the environmental eMergy contribution is 100.88 E19 sej/yr, and the total eMergy produced by forest biomass over a year (line 4) is 100.7 E19 sej/yr, which is practically the same value. This eMergy total is calculated by multiplying the total energy produced by the forest as biomass, 5.92 Joules, by its transformity of 1.7 E4 sej/yr.

In the second section (BB'), Table 6, logs have been harvested from the varzea forest and transported to Itacoatiara's industries. By this time several agents have contributed energies to the process:

a) the embodied energy in the logs themselves (line2);

b) the river kinetic contribution by floating the logs downstream (line 1);

Table 6
EMERGY EVALUATION OF INCOMING LOGS

SECTION LINE BB

Note	Item	Units/yr	Transformity sej/unit	Solar eMergy E18 sej/yr
ENVIRONMENT				
1	River Kinetic J	3.40E+11	4.10E+04	0.01
2	Wood(in) J	3.35E+15	1.70E+04	56.93
	Sum of Environmental eMergy Contribution (I)			56.93
FEEDBACK				
3	Transpor Felling$	6.00E+06	6.08E+12	36.48
	Sum of Human eMergy Contributions (F)			36.48
PRODUCTION PROCESS				
4	Logs J	3.35E+15	2.79E+04	93.41
	Sum of Production Processes (Y)			93.41

RATIOS

Net eMergy Yield Ratio = Y/F = (9.34 E19 /3.65 E19) = 2.56
eMergy Investment Ratio = F/I = (3.65 E1 /5.69 E19) = 0.640791

Transformity of Incoming Logs =
Total eMergy used/energy production = (5.69E19+3.65E19) /3.35E15 2.79E+04

NOTES:

1 River Kinetic Contribution to Log Transport (Mississippi Report, p51-53) Rio Madeira's basin is considered in calculations. Water displaced by logs/yr:
(2.5 E5 tons/yr)(0.9 ton/m3) = 2.25E+05 m3/yr
River volume - 1E10 m3/yr, Gibbs Free Energy :
(1 E10 m3/yr)(1 E6 g/m3)(5 J/g) = 5E+16 J/yr.
Geopotential energy which goes into Kinetic Energy during flow: 100 m average elevation, Gravity 9.8 m/sec2:
(1 E10 m3/yr)(100 m)(1 E3 kg/m3)(9.8 m/sec2)= 9.8E+15 J/yr.
Fraction of river used by logs: (3.7 E5 m3/yr)\(1E10 m3/yr)= 3.70E-05 (Mississippi River Basin Report, 1987, p. 51)
Fraction of River's Geopotential Energy:
(3.70-E5)(9.8 E15 J/yr)= 3.40 E11 J/yr

2 Incoming Wood - (tons timber felled/yr)
(250000 m3/yr)(0.8 E6 g/m3)(4Kcal/g)(4186 J/Kcal)=
3.35E+15 J /yr

3 Timber felling and transport services -
Logs are paid for at the same value in three different phases of transport: 1) at the riverside, after being felled by families; 2) at riverside after having been assembled by 2 different groups; 3) at riverside by the mill.
(250,000 m3)($ 8.00/m3)*3 6.00E+06 $

4 Logs - (Bruce,personal comm.)

c) goods and services of felling and trasporting logs, and the fuels involved (line 3).

The total eMergy used, from human processes (F) and from natural inputs (I), or F + I, of 94 E18 sej/yr, divided by the energy produced (Y - yield of logs harvested and transported), of 3.35 E15 Joules, gives the transformity for the product (logs, FOB Itacoatiara) of 2.79 E4 sej/J. This is 164 % higher than the biomass tranformity for the varzea's wood production because it includes the kinetic energy contributed by the river in floating the logs downstream, the goods and services involved in felling and transport, and the fuels.

The eMergy contributions from human processes (F - Feedback) are 39.4 % (36.48 E18 sej/yr) of the total eMergy used to get the logs to industry, while nature's contribution (I - Input) is 60.6 % (56.9 E18 sej/yr). This results in an **eMergy Investment Ratio** of 0.64 (see Figure 12), reflecting the fact that the energy supplied by human processes is lower than that contributed by nature. Up to this point in the process there is a very low intensity of development, i.e. just the felling and transporting of the logs.

For the harvest and transport of the energy contained in the logs, 3.35 E15 Joules (line 4 - Table 6), which is the product in this process (Y - Yield), we had a human contribution of 36.48 E18 sej/yr (F). Dividing Y by F we obtain the **Net eMergy Yield Ratio** of 2.56. For each unit of energy contributed by human processes we obtain 2.56 units of produced energy, in the form of sawn logs.

In the third section, CC', Table 7, logs have been transformed to the finished product, plywood and veneer, through the interaction of the industrial processes. Thus all inputs to industry: environmental, construction and operational, which include the town's labor contribution, are considered. To evaluate the eMergy contribution of incoming logs we use the log's transformity from the previous table of 2.79 E4 sej/J.

By this stage the process of plywood production has acquired new inputs of eMergy, resulting in added overall eMergy and a higher transformity (2.39 E5 sej/J), 87.2 % higher than in Section BB'. Also Section CC' has a greater **eMergy Investment Ratio** than the previous section (Section BB'), 1.56 as against 0.64. The **Net eMergy Yield Ratio** has substantially decreased: 1.66 as against 2.56. More eMergy used for lesser production, 9.87 E14 Joules of produced veneer and plywood, against 3.35 E15 Joules of energy contained in the logs arriving to be processed (see logs' path in section BB').

Flows of money are already present in section BB' through the combined costs of felling and transport and associated fuels. In section CC' money flows come from sales to external markets; money

Table 7

EMERGY EVALUATION OF THE SYSTEM OF ITACOATIARA

SECTION LINE CC

Note	Item		Units/yr	Transformity (sej/unit)	Solar Emergy (E18 sej/yr)
ENVIRONMENT					
1	Logs	J	3.35E+15	2.80E+04	93.77
	Sum of Environmental Emergy Contribution				93.77
FEEDBACK					
	Construction inputs				
2	Wood	g	1.86E+07	3.75E+08	0.01
3	Concrete	g	8.85E+07	9.26E+07	0.01
4	Steel	g	5.40E+06	1.80E+09	0.01
5	Furnishings	g	5.76E+05	4.00E+06	0.00
6	Machinery	g	5.38E+07	6.70E+09	0.36
	Operational inputs				
7	Logs cost	$	6.00E+06	6.08E+12	36.48
8	Firewood/boiler	J	1.93E+15	3.49E+04	67.32
9	Electricity	J	3.26E+13	2.00E+05	6.51
10	Fuels	lit	2.32E+06		6.74
11	Labour services	$	1.54E+06	6.08E+12	9.36
12	Auxilliary serv	$	1.02E+06	6.08E+12	6.20
13	Transport FOB	$	4.44E+05	6.08E+12	2.70
14	Assets/year	$	1.00E+06	6.08E+12	6.08
	Sum of purchased inputs (F)				141.78
PRODUCTION PROCESS (Y)					
15	Veneer & Plywood	J	9.87E+14	2.39E+05	235.89

RATIOS

Net Emergy Yield Ratio = Y/F =	2.37E20/2.95E2	1.66
Emergy Investment Ratio F/I =	2.95E20/9.38E1	1.51

Transformity of Finished Product (Veneer & Plywood) = Total Emergy/Yield (energy)
(I+F)eMergy /(Y)energy =(9.38E19 + 2.95E20)/9.87E1 2.39E+05 sej/J

NOTES

1 Logs - (25000 m3/yr)(0.8 E6 g/m3)(4Kcal/g)(4186 J/Kcal)= 3.35E+15 J /yr
Data for items 1 to 8 obtained from interviews and site visits.

2 Wood - ((108000 m2)(3kg/m2)(1000 g/kg)+(4800 m2)(10 kg/m2)(1000 g/kg)) / 20 yr = 1.86E+07 g /yr

3 Concrete -{ [(108000 m2)(.1 m)+(4800 m2)(.07 m)](2500 kg/m3)(1000 g/kh) } / 20 yr = 1.77E+09 g /yr

4 Structural Steel - [(108000 m2)(20 kg/m2)(1E3 g/kg)]/20 yr 1.08E+08 g /yr

5 Furnishings-[(4800 m2)(.3)(.2 m)(800kg/m3)(1000g/kg)]/20yr 1.15E+07 g /yr

6 Steel in Machinery - [(2743.5 m3)(7.84E6g/m3)] /20 yr = 1.08E+09 g /yr

7 Logs cost - (250000 m3)($ 24/m3) = 6.00E+06 $ /yr

8 Firewood for Boilers - (12000 m3/month)(12 mth/yr)(800 kg/m3)(1000 g/kg)(4Kcal/g)(4186 J/Kcal) = I.93E+15 J /yr

9 Electricity - (9045520 KWH/yr)(860 Kcal/KWH)(4186 J/Kcal)= 3.26E+13 J /yr
Figures from CEAM - Amazon State Elect.Co.(Oct'90/Sept'91)

10 Fuels - 2.32 E6 liters/year; from PETROBRAS-Manaus.

11 Data of items 11 to 15 from site visits and interviews.

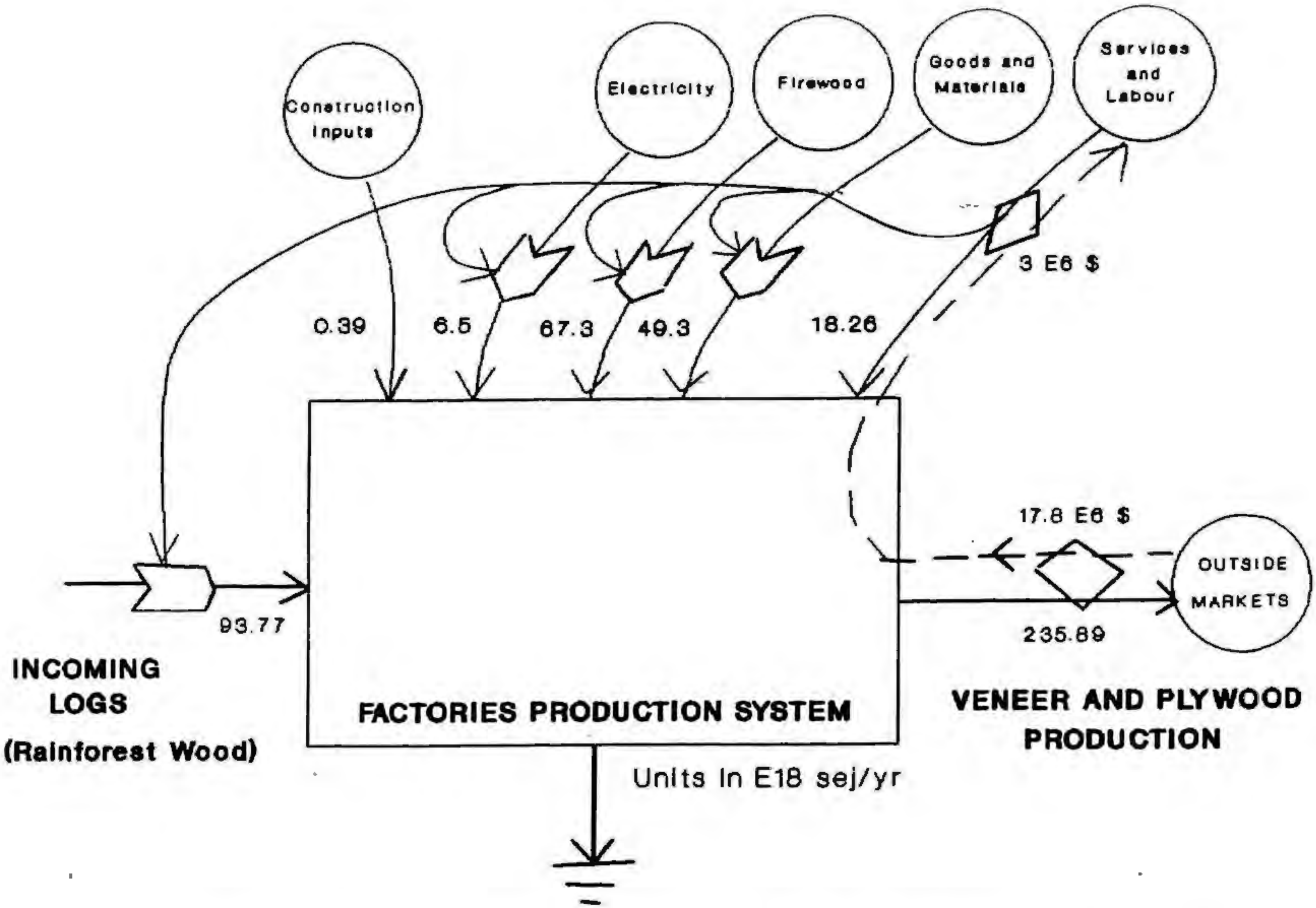


Figure 13 - Plywood factories production system (eMergy units)

is partially used locally by industry, spent for goods and services for construction and operational costs, and for labor. The greatest part goes outside of the system to external investments (see figures 12 and 13). Figure 13 summarizes the production system of the plywood mills.

The fourth section (DD'), Table 8, presents an overview of the town of Itacoatiara and of the eMergies that were contributed to its construction. It is an approximation of the last 20 years of the town's development. The flows considered are yearly flows of materials, goods and services.

In this section, to obtain the same eMergy ratio in the production of plywood and veneer (9.87 E14 Joules/yr) a much greater investment is needed. The whole town is considered as the necessary structure which supports the great labor force indispensable for industry. The town is the investment industry makes indirectly, jointly with the government and the local population, to maintain its volumes of supplies and production, and the quality of its products.

As might be expected, the eMergy Investment Ratio is extremely high (364.37) as man-made eMergies greatly outnumber those from the environment, and the Net eMergy Yield Ratio of 1.037, is lower than in section CC' (1.66). Transformity for plywood production is 163% higher: 3.9 E5 sej/J, as against 2.39 E5 sej/J in Section CC,as the same amount of plywood is produced with a higher eMergy investment.

Table 8
EMERGY EVALUATION OF THE SYSTEM OF ITACOATIARA

SECTION LINE DD

Note	Item	Units/yr		Transformity (sej/unit)	Solar Emergy (E18 sej/yr)
ENVIRONMENT					
1	Rain-Chem.Pot	J	7.02E+13	1.50E+04	1.05
	Sum of Environmental Emergy Contribution				1.05
FEEDBACK					
	Construction inputs (public works)				
2	Road pavings	$	1.15E+06	6.08E+12	6.97
3	Street lighting	$	4.67E+05	6.08E+12	2.84
4	High tension ne	$	9.00E+05	6.08E+12	5.47
5	Water services	$	4.67E+05	6.08E+12	2.84
6	Educat.building	$	8.90E+04	6.08E+12	0.54
7	Health install.	$	2.50E+04	6.08E+12	0.15
8	Port Installatn	$	1.25E+05	6.08E+12	0.76
9	Admin.buildings	$	1.44E+04	6.08E+12	0.09
	TOTAL PUBLIC WORKS CONSTRUCTION				19.66
	Construction inputs (private sector)				
10	Residenc/Stores	$	2.68E+06	6.08E+12	16.26
11	Other factories	$	1.00E+06	6.08E+12	6.08
	TOTAL PRIVATE CONSTRUCTION				22.34
	Operational inputs				
12	Fuels	J			4.39
13	Electricity	J	7.78E+13	2.00E+05	15.55
14	Goods	$	3.38E+07	6.08E+12	205.50
15	Labour services	$	1.71E+07	6.08E+12	103.85
16	Assets/year	$	1.82E+06	6.08E+12	11.07
	TOTAL OPERATIONAL INPUTS				340.36
	SUM OF TOTAL TOWN'S INVESTMENTS (F)				383.42
PRODUCTION PROCESS (Y)					
17	Veneer & Plywood	J	9.87E+14	3.90E+05	384.93

RATIOS

Net Emergy Yield Ratio = Y/F	397.7E18/383E18	1.0039
Emergy Investment Ratio F/I =	383.4E18/1.05E18	364.3747

Transformity of Finished Product (Veneer & Plywood) = Total Emergy/Yield (energy)
(I+F)eMergy /(Y)energy =(1.05E18+383.42E18)/9.87E14= 3.90E+05 sej/J

NOTES

1 Rain - Chemical Potential - (city area)(precipitation ave.)(G)
(9 km2)(1E6 m/km2)(1.5589 m/yyr)(5 J/g)(1E6 g/m3)= 7.02E+13 J

2-11 Data of items 2 to 11 from local authorities and loca IBGE office (Instituto Brasileiro de Geografia e Estatística).

Table 8 (continued)

12 Fuels - (83.8 T/yr)(44 E9 J/T)+(1106 T/yr)(44 E9 J/T)+
+(375 T/yr)(44 E9 J/T) =
3.68 E12 J (diesel)+4.86 E13 J (gasoline)+1.65 E13 J (ethanol)=
Converting to eMergy:
(3.68 E12 J)(5300 sej/J)+(4.86 E13 J)(66000 sej/J)+(1.65 E13 J)(60000sej/J)=
= 4.39264 sej/yr

13 Electricity - Total Use - Veneer processing factories
(3.07E7 KWH - 0.904 E7 KWH)(860 Kcal/KWH)(4186 J/Kcal)= 7.78E+13 J/ yr
(source CEAM - Amazon State Elect.Co.- Oct'90/Sept'91)

14 Goods - 50% population (5000 families) spends $ 25/week on food and
$ 15/week on other goods.
30% population (3000 families) spends $ 40/week on food and
$ 30/week on other goods.
20% population (2000 families) spends $ 70/week on food and
$ 50/week on other goods.
(5000)($40/wk * 52 wk/yr) + (3000)($70/wk)(52 wk/yr) + (2000)($120/wk)
(52 wk/yr) = 3.38E+07 $ /yr

15-16 Data from Amazon State Finances office, ICOTI, Itacoatiara's Public Works Dept.

Comparisons between Sections CC' and DD'

When the town is considered as the structure responsible for the production of veneer and plywood, a higher transformity results, as seen in the preceding paragraph. The total yearly investment made by the town is 383.42 E18 sej/yr, as against industry's investment of 141.78 E18 sej/yr. The town is therefore responsible for the investment and management of 73 % of the eMergy used, whilst industry is responsible for only 27 %. In both systems, the same eMergy that enters exits: 397.58 E18 sej/yr come in for the town, and 397.76 E18 sej/yr exit in the form of plywood; 235.55 E18 sej/yr are used by industry and 235.89 E18 sej/yr are produced.

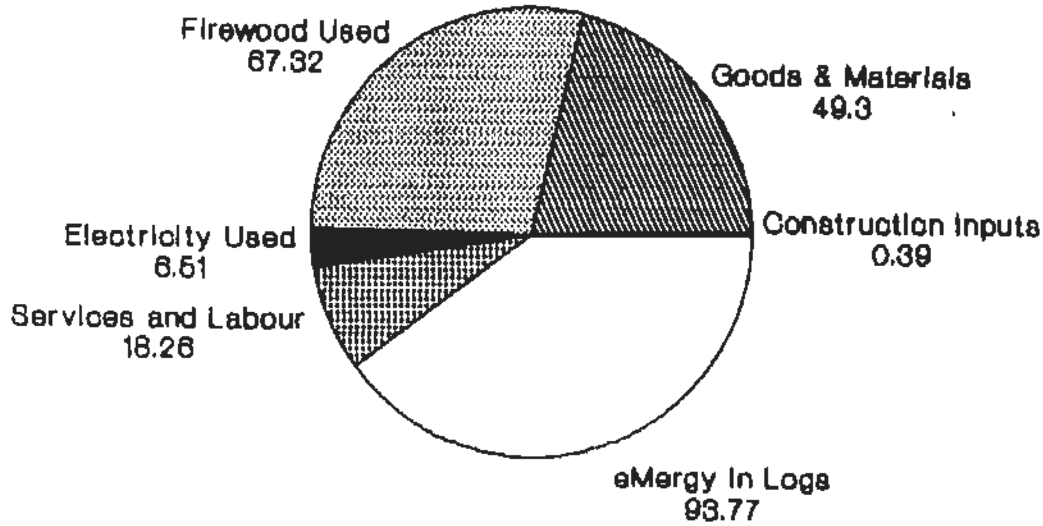
Total operational inputs for the town (351.95 E18 sej/yr) exceed those from industry (141.78 E18 sej/yr), but they are only 2.4 times higher. This indicates that **24 % of the town's eMergy economy is represented by industry.**

The greatest eMergy flow during the year for industry is from the logs, with 40% (Table 9 and Figure 14), followed by firewood (29%), which comes partly from the recycling of unused timber and partly from purchased firewood (I was unable to get data on relative proportions). Goods and materials, including a little fuel, are third with 21%. Services and labor, electricity and construction inputs are responsible for, respectively, 8%, 3% and 0.2% of total eMergy flows.

Table 9 - eMergy flows for Industry and Town

Item No.	Description	eMergy Value E18 sej/yr	%
eMergy Flows in Factories Production System			
1	eMergy in Logs	93.77	39.81
2	Construction Inputs	0.39	0.17
3	Goods & Materials	49.3	20.93
4	Firewood Used	67.32	28.58
5	Electricity Used	6.51	2.76
6	Services and Labor	18.26	7.75
	TOTAL	**235.55**	**100.00**
eMergy Flows within Town			
1	Veneer & Ply Output	397.76	49.99
2	Electricity Used	31.1	3.91
3	Assets/Year	11.07	1.39
4	Goods & Services	205.5	25.83
5	Constructn., Private	22.34	2.81
6	Constructn., Public	19.66	2.47
7	Service and Labor	103.8	13.05
8	Fuel Used	4.39	0.55
	TOTAL	**795.62**	**100.00**

PROPORTIONAL EmERGIES SPENT BY INDUSTRY
Factories Production System



Units in E18 sej/yr

PROPORTIONAL EmERGIES SPENT BY TOWN
Town's Yearly eMergy Flows

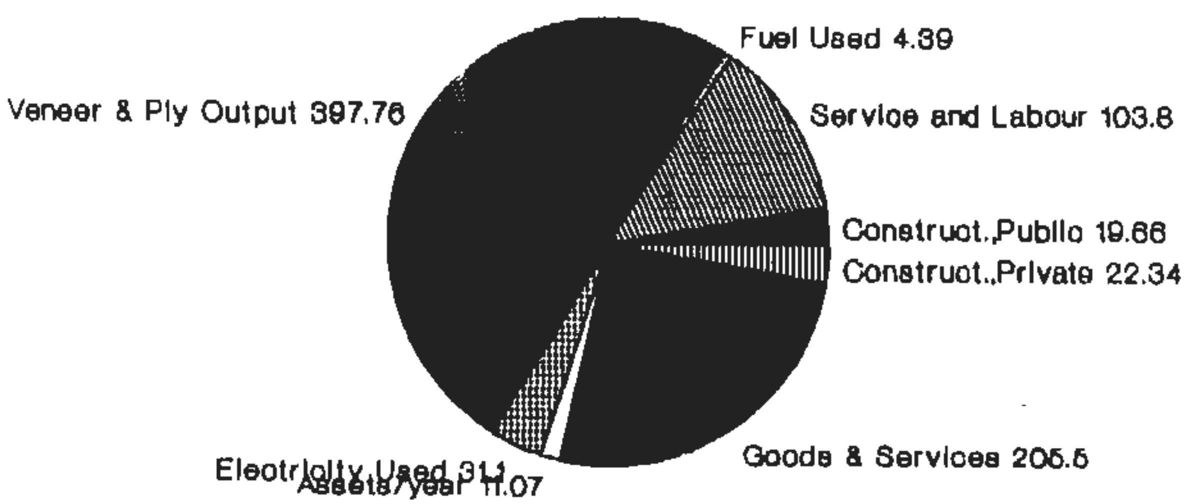


Figure 14 - Proportional eMergies spent by Industry and Town

The major yearly eMergy flow within the town of Itacoatiara is the production of veneers and plywoods, at 49.99%, exactly half of all flows. As expected, goods and services take the next slice at 25.83%, followed by services and labor, 13.05%, electricity, 3.91%, private and public construction, 2.81% and 2.47% respectively, and finally fuel used, at 0.55%.

DISCUSSION

Country Overview

The Emergy analysis indicates the state of transition of the Brazilian economy. Brazil's Emergy/money ratio is almost twice the world average of 3.8 E12 sej/$, which clearly classifies the country within the bracket of the less developed countries. Brazil's eMergy/capita ratio (3.4 E15 sej/person*yr) is relatively low. India's ratio is 1.0 E15 sej/person and the United States is 29 E15 sej/person (Odum 1987). This might imply that there is an abundant population relative to resources. The country has a mining and agricultural base with a potential for increased production of hydroelectricity, which would have to be checked against social and environmental losses resulting from ecological changes in the occupied areas. Brazil has a net eMergy loss from its trade, which is not directly due to the deficit in its balance of payments, but rather to the fact that much value is exported in mining, timber and agricultural products. Thus, this imbalance is due to exports of raw materials, which make up 98.96% of the total exports.

Analysis of the economies of other nations (Odum and Odum, 1983) led to a broad classification of national economies based on their exports as "consumer" nations and "provider" nations. If a nation imports more eMergy than it exports, it is classified as a "consumer" nation; when it exports more than it imports, it is a "provider" nation. Provider nations can be classified further on the basis of the composition of their exports. Nations whose exports are composed largely of raw resources (in quantities greater than 50%) are "resource providers". When exports are composed mostly of upgraded, intermediate, or finished products the exporting nation is considered "commodity provider". Brazil is then a resource provider.

Relationship between Veneer and Plywood Industry and Itacoatiara

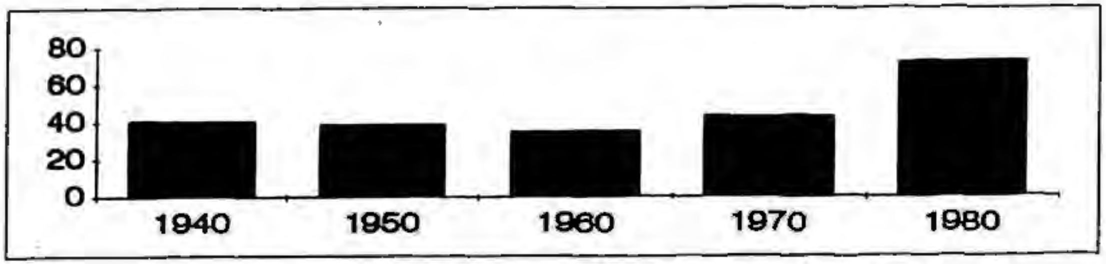
Itacoatiara's rate of urbanization presented a distinct change in the eighties, from a steady 35 to 42% per decade from 1940 to 1970, to a high 71.8% in 1980, corresponding to the installation of the plywood industry. Population also jumped from a constant 37000 during the 1970s to almost 60000 in 1987 (Figure 15).

Comparing Investment Ratio of Plywood with that of Brazil

One clear indication of the facilities available to industry at the time of its installation (besides closeness to raw resources, generous state fiscal incentives and cheap labor), is the comparison between the Investment Ratio of the Plywood mills with that of Brazil as a whole. In this case one compares how much eMergy was produced through the process of plywood manufacture and how much that money was worth to industry. Thus, in 1989, for a production of 235.89 E18 sej/yr of plywood output, industry received US $ 17.8 million. Dividing the eMergy by the money one obtains the eMergy/money value of 13.26 E12 sej/$. This is 2.18 times greater than that of Brazil (6.03 E12 sej/$, Table 2). It means that 1 dollar invested in Itacoatiara's eMergy economy, from the industry's point of view, gets twice the eMergy result than it would, on average, if invested somewhere else in the country. However, this doesn't however imply a just or better social

ITACOATIARA
Urbanization Rates

Years	% Increase
1940	40.59
1950	38.67
1960	34.86
1970	42.67
1980	71.8



Population Growth

Years	Population
1940	11681
1950	15173
1960	25627
1970	37346
1980	37237
1987	59678

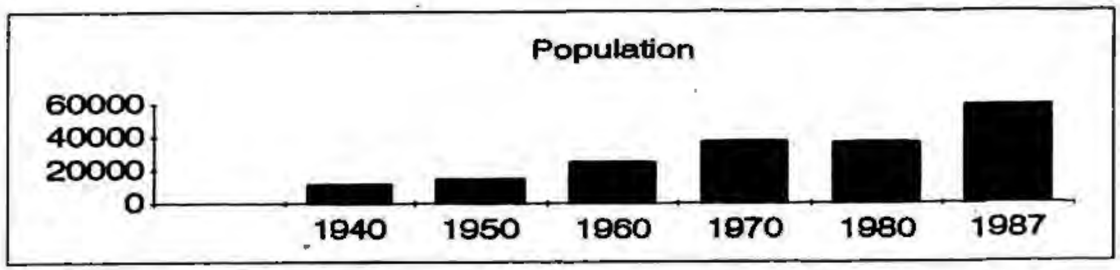


Figure 15 - Itacoatiara's Population Increases and Town's Growth Rates.

arrangement, since results are better overall. Prices paid for wages for factory labor are very low and working conditions hard. Industry maintains that this has to be done to be able to compete with the international market, while the few and poorly-organized trade unions challenge this view arguing that all benefits exit the town's boundaries and that companies do not invest sufficiently back into the town's structure.

eMergy Investment Ratio as an indicator of the intensity of development

In section line BB' (Table 6), when the logs are coming in from the forest, there is little investment. The plywood production process registers in this phase an Investment Ratio of 0.64/1, which, even at this early stage, is already 10 times the average Investment Ratio for Brazil (0.064/1, Table 3 - line 22). As logs proceed further into the industrial process the Investment Ratio jumps to 1.51/1 (Table 7 - section line C), or 2.36 times higher, almost 24 times that of Brazil. Finally, if we consider the whole town as a responsible part of the process we reach a high of 364.37/1, which is around 50 times the average for United States.

The comparison between regional Investment Ratios and the ratio for existing or proposed developments may be used as an indicator of the intensity of the development within the local economy.

Within the scope of this study it wasn't possible to gather sufficient data to determine a Regional Investment Ratio which could have been compared with the process of plywood production within the system under study. However, judging by the concentration of industrial, commercial and service industry in Manaus, the capital of Amazonas State, within the great spatial extent of the Amazon forest, the Regional Investment Ratio should be even lower than that of Brazil (0.064/1, Table 3 - line 22). This would reinforce the argument that the process of timber extraction and plywood processing have much higher eMergy Investment Ratios than the average for Brazil.

Comparing Log Felling and Transport eMergies to Dollars paid FOB Itacoatiara

Up to the 1990s logs were cut and assembled in a very dispersed fashion almost entirely by family working units. A typical family working unit would consist of a father and two sons, would fall about ten trees per year in the low water season (amounting to 20 cubic meters in varzea conditions), and carry them downstream as rising water levels would permit, assembling them into a batch ready for the buyer. This intermediate buyer would join various logs with his small boat and leave them at a further point downstream where he would then pass them on to another buyer. By this time there would be around 200 logs (approx. 400 cubic meters). The complete raft to industry, averaging 4000 cubic meters, would then be taken downstream by bigger boats. The assembling of logs into rafts is a real art which uses lighter logs to support heavier ones (greater relative density) in a network connected by cables and specially wrought hooks.

A fixed price is paid for the product for each step along these economic transactions . This price totals US $ 24.00 FOB Itacoatiara (in 1991). However, if one calculates the approximate eMbodied energy expenditures along this process, one comes up with quite a different value, which is more than 10 times greater (exactly 12.25 times, see Table 10 for calculations). In eMergy equivalents the dollar value of logs, FOB Itacoatiara, is 3.65 E19 sej/yr, while for the total emergies involved, having calculated labor, transport, fuels and equipment depreciation, one obtains the figure of 4.47 E20 sej/yr. It is important to mention in relation to international export trade that the average log export price paid in 1989 in the state of Amazonas was of US$ 9.48 (Hummel et al, 1993), thus making eMergy expenditures 31 times greater than the eMergy dollar value paid for exported logs. It must be said that these are very rough calculations of volumes and manpower expenditure, but they represent reasonable accurate orders of magnitude. **This difference denotes the inability of money to**

Table 10
CALCULATIONS IN EmERGY EXPENDITURES

1. Calculating TRANSFORMITY of one individual in Brazil (1989 data)
Total National eMergy / Capita = (2.27 E24 sej/yr)/(147.3 E6 people)=
1.54E+16 sej/person/yr
Transformity per Person (National Avarage) =
National eMergy/Capita / Energy Requirement/Capita =
(1.54 E16 sej/person/yr)/(3.82 E9 J/person/yr)= 4.03E+06 sej/J
Note: Energy Requirement/Capita =
(2500 kcal/day)(365 days/yr)(4186 J/kcal) = 3.82E+09

LEVEL 1 - family extractivism (20 m3/lot)
Manpower: (112,500 Man-days)(2500 kcal/day)(4186 J/kcal)(4.03 E6 sej/J)=
4.74E+18 sej/yr
Fuel: (1,375,000 lit/yr)(44 E9 J/T)(6.6 E4 sej/J)=
3.99E+18 sej/yr
Material Depreciation and Maintentance Costs:
($ 50/chainsaw + $ 50/boat)(12500 work groups)(6.08 E12 sej/$)=
7.60E+18 sej/yr
TOT.L1 = 1.63E+19 sej/yr

LEVEL 2 - first assembly (400 m3/lot)
Manpower: (50,000 Man-days)(2500 kcal/day)(4186 J/kcal)(4.03 E6 sej/J)=
2.11E+18 sej/yr
Fuel: (125,000 lit/yr)(44 E9 J/T)(6.6 E4 sej/J) =
3.63E+20 sej/yr
Material Depreciation and Maintentance Costs:
($ 30,000/boat)(34 boats)(10%)+($ 30,000/boat)(34 boats)(10%)*
*(6.08 E12 sej/$) =
1.24E+18 sej/yr
TOT.L2 = 3.66E+20 sej/yr

LEVEL 3 - second assembly (4000 m3, prepares raft)
Manpower: (3750 Man-days)(2500 kcal/day)(4186 J/kcal)(4.03 E6 sej/J)=
1.58E+17 sej/yr
Fuel: (18,750 lit/yr)(44 E9 J/T)(6.6 E4 sej/J) =
5.45E+19 sej/yr
Material Depreciation and Maintenance Costs:
(($80,000/boat)(4 boats)(10%)+($80,000/boat)(4 boats)(10%))*
*(6.08 E12 sej/$) =
3.89E+17 sej/yr
TOT.L3 = 5.50E+19 sej/yr

LEVEL 4 - complete raft to industry (4000 m3)
Manpower: (5000 Man-days)(2500 kcal/day)(4186 J/kcal)(4.03 E6 sej/J)=
2.11E+17 sej/yr
Fuel: (250,000 lit/yr)(44 E9 J/T)(6.6 E4 sej/J) =
7.26E+20 sej/yr
Material Depreciation and Maintenance Costs:
(($100,000/boat)(4 boats)(10%)+($100,000/boat)(4 boats)(10%))*
*(6.08 E12 sej/$) =
4.86E+17 sej/yr

Table 10 (continued)

TOTALS

LEVEL 1 - family extractivism (20 m3/lot)	1.63E+19 sej/yr
LEVEL 2 - first assembly (400 m3/lot)	3.66E+20 sej/yr
LEVEL 3 - second assembly (4000 m3, prepares raft)	5.50E+19 sej/yr
LEVEL 4 - complete raft to industry (4000 m3)	4.86E+17 sej/yr
Totalling	4.38E+20 sej/yr

CALCULATIONS IN MONETARY VALUES ($)

LEVEL 1 - family extractivism (20 m3/lot)

Value of logs at riverside $ 8.00/m3
(250,000 m3)(8 $/m3) = 2.00E+06

LEVELS 2-3 - first assembly (400 m3/lot)

Value of logs ar riverside $ 8.00/m3
(250,000 m3)(8 $/m3) = 2.00E+06

LEVEL 4 - complete raft to industry (4000 m3)

Value of logs ar riverside $ 8.00/m3
(250,000 m3)(8 $/m3) = 2.00E+06

Totalling (in Us dollars) - 6.00E+06
and in eMergy Equivalents (6 E6 $)(6.08 E12 sej/$)= 3.65E+19 sej/yr

COMPARING ENERGY EVALUATION AND DOLLAR VALUE

Energy eval. for process - 4.38E+20 sej/yr
Economic evaluation - 3.65E+19 sej/yr

This difference denotes the inability of money to represent a true measure of energy expenditure and of real costs.

represent a true measure of energy expenditure and of real costs. Here it would be wise to say that much work needs to be done to educate industry at a national and international level to put back into the environment a certain fraction of its net income. This is especially so now, when the emerging trend is one of entering varzea forest with heavy tractors and carting logs out with barges, as demand is growing and traditional varzea areas in the Rio Madeira are practically depleted of species useful to the plywood industry.

SIMULATION

The operation of a system can be simulated by generating its patterns with time. Simulation shows how a system behaves with time.

Macroscopic Minimodels

Macroscopic minimodels are a family of models that can help construct a large scale overview of the ecologic and economic components of a specific system under investigation. They are macroscopic in that they represent a broad overview of the main determining components and the forcing functions within a system, its inputs and outputs and its workings within a larger system. They are also minimodels in that they aggregate various factors and simplify the general picture to quickly identify certain basic questions and define possible tendencies of that system with changes in the prevailing conditions. The integration of monetary flows within these models allow them to explore fundamental relationships between prices of production sold and goods acquired, between population and production of sawmills, in our case, between resources extraction rate and environmental impacts. The modeller tries to allocate functions to aggregated components in a search to simplify complexity.

The general value of models is that they can test hypothesis, such as whether a system will furnish sustainable yields or whether it will fall into a 'boom and bust' situation. They can assist in finding ways of reaching a more balanced and sustainable state, or simulate the system's response to a crash in world economy. Their great asset is also in serving as visual aids through the generation of families of curves such as differing cutting rates on forest with everything else remaining constant, etc.

Model conception

A model, as a summary of the important parts of a system, represents a decision as to what activities are essential in that system. Using the symbols in Figure 2, the relationships between sources, parts, storages and products are graphically defined in a diagram. System behavior results from these relationships. The system diagram is not just an important visual tool that establishes components, functions and connections, but a mechanical statement that defines mathematical relationships, produces a set of related equations, written from the relationships shown, and integrates them into a computer program. These equations represent changes of each stored quantity. Running this program simulation with avaliable data, or even with made-up data, can provide a useful indication of what the system will do over a period of time.

Digital iteration

Digital iteration is accomplished by successive calculations of the quantities in the storages as they change with inflows and outflows. Inflows and outflows are added or subtracted at each calculation at regular time intervals. The existing storage quantity is calculated by incrementing it with its inputs or diminishing it by its outputs, during a time interval, the result being plotted as a point on a graph, or written down as a value. Calculation is then repeated for the next time interval. This series of discrete steps is called iteration and the process is a digital one because it is not one of continuously varying functions. This digital simulation is the successive evaluation of difference equations that represent the system.

Difference equations

In the simulation of more complex systems, where there are more than one storage, each storage is defined by a rate equation with its own program line. A difference equation shows the time changes within a system. At a given time the quantities are those at the time of the last calculation plus the increments added for the short time interval _i_ since the last calculation, as in:

$$Q\ t + 1 = Qt + i\ (J - KQ) \qquad (1\text{-}1)$$

Here the quantity Q after the next time interval (t + 1) will be the quantity at time t plus the increment that is the flow rate (J - KQ) times the elapsed interval of time i. Reiterated calculations of the difference equation provide a running calculation of the quantities in a storage.

The change increments, or DQ statements, are calculated before increments are added to the storages. A limiter is included after each statement for a storage quantity Q so that it cannot go below zero as in Equation (1-2)

$$\text{IF } Q < 0, \text{ THEN } Q = 0 \qquad (1\text{-}2)$$

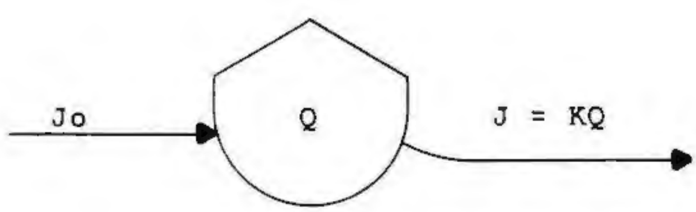
Values for J and K and initial values for T and Q are put into the computer's memory location (T = 0, q = 0, J = 1, K = 0.5). A value for Q at time step 1 is calculated according to the difference equation ($Qt+1 = Qt + J - kQt$) and the new value for Q replaces the old value. Time is then advanced by 1 time unit and the calculation is repeated. With each iteration loop, the values of T and Q at that time are plotted; K and J maintain their values as constants.

Programming in BASIC

Instructions in BASIC computer language use simple English words with numbered common lines, by which the computer programs the sequence of operations. On the instruction to "plot" it generates a graph. The simulation can be run again by changing some property such as the energy source, I, or the initial starting conditions, Q1, resulting in a new graph.

Rate equations

As equations constitute a systems language they indicate how separate terms, which represent components, or parts, within a system, should be combined. The rate equation sums the rates of contributions or subtractions from a storage, see figure.



$$Q = Jo - KQ$$

Rate of change of Q with time	=	inflow rate	- outflow rate (dependent on quantity stored)

Rate equation for storage.

As outflow J depends on the stored quantity, the flow can be represented as a product of the transfer coefficient and the quantity Q.

$$Q = Jo - KQ \qquad (1 - 3)$$

The rate of change is the balance of inflow Jo and outflow KQ, including heat losses from the storage and its pathways. The rate of change of Q with time is shown by a dot over the letter Q.

" The energy circuit diagram shows the relationship of storages and flows pictorially and thus represents the differential equation very simply and equally rigorously with one pathway for each term in the equation. " (Odum, 1982).

Calibration

Once data are available for most of the components in the model coefficients for the different pathways are calculated. Coefficients indicate flow rates along pathways and their values can be either observed data measured from real situations or made-up numbers to test model response.

The quantity processed per unit time, or flow, is expressed in numbers for calibration purposes, and so are storage quantities. Usually a steady state condition is assumed to calibrate the model. Equations are written for each pathway and the mathematical term for the pathway is equated to the value of the flow.

Storage values substitute storage mathematical symbols to solve equations. Finally a spreadsheet may be used to calculate the model's coefficient. Thus with any value change in the table the program will recalculate any coefficient affected by the change (Table 11).

Model of Itacoatiara's Plywood Industry and Population

This macroscopic minimodel represents the impact of logging on natural resources, according to increased or diminished industrial gains and assets, oil and labor prices, as well as the relationships between industrial success or failure, population growth and immigration, and Itacoatiara's assets.

The model uses forest timber, purchased inputs and available labor of people who immigrate to generate useful products for exports. According to the model's diagram (Figure 16), natural resources on the left provide energy (I), which interacts with forest wood or biomass (W). From the stocked biomass (W) logs are harvested (L) at the rate dictated by assets (A). Rate of log harvesting also depends on market price (P1) for the finished product, on prices of goods and services (P2) and fuel (P3), and has a certain effect on population numbers (N). Outside population (OP) is attracted to the town by increase in assets (A), dependent on money invested by industry (JM) and money from plywood sales.

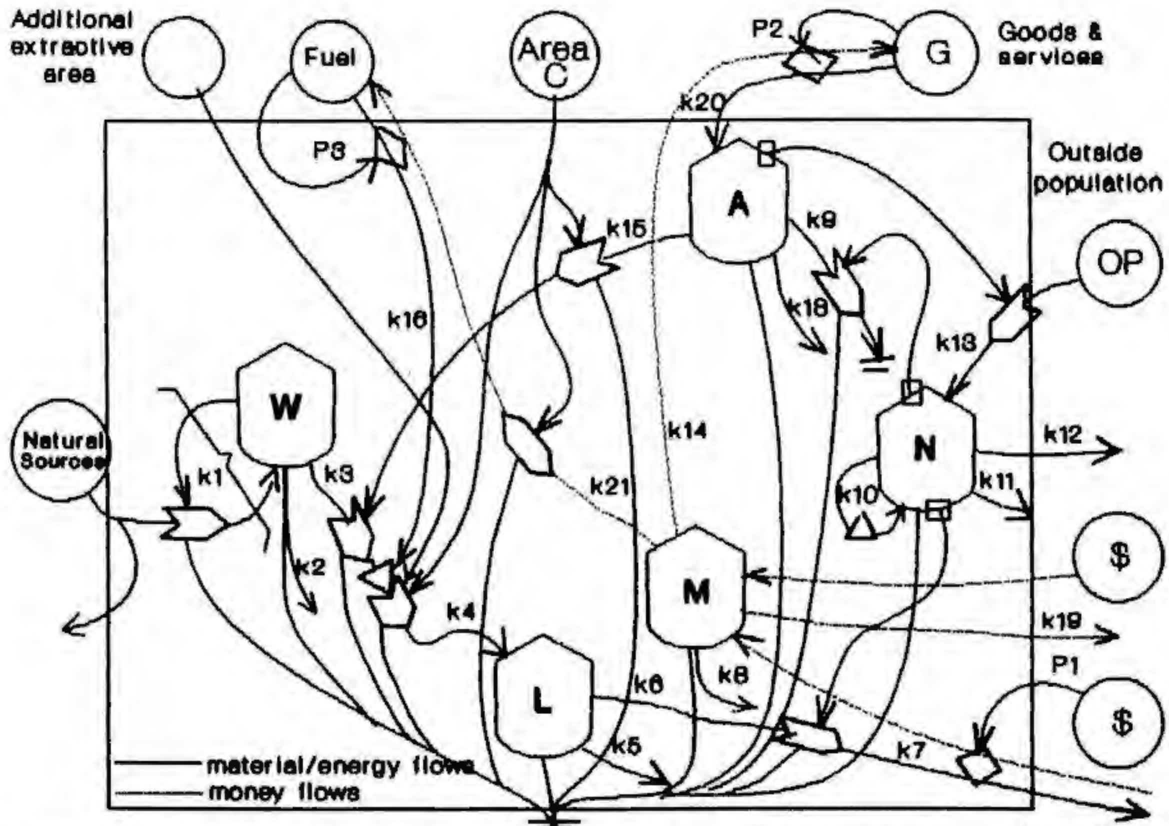


Figure 16 - Energy simulation model: W:forest wood stock; A: town's assets; L: Log stock; M: Money; N: Population.

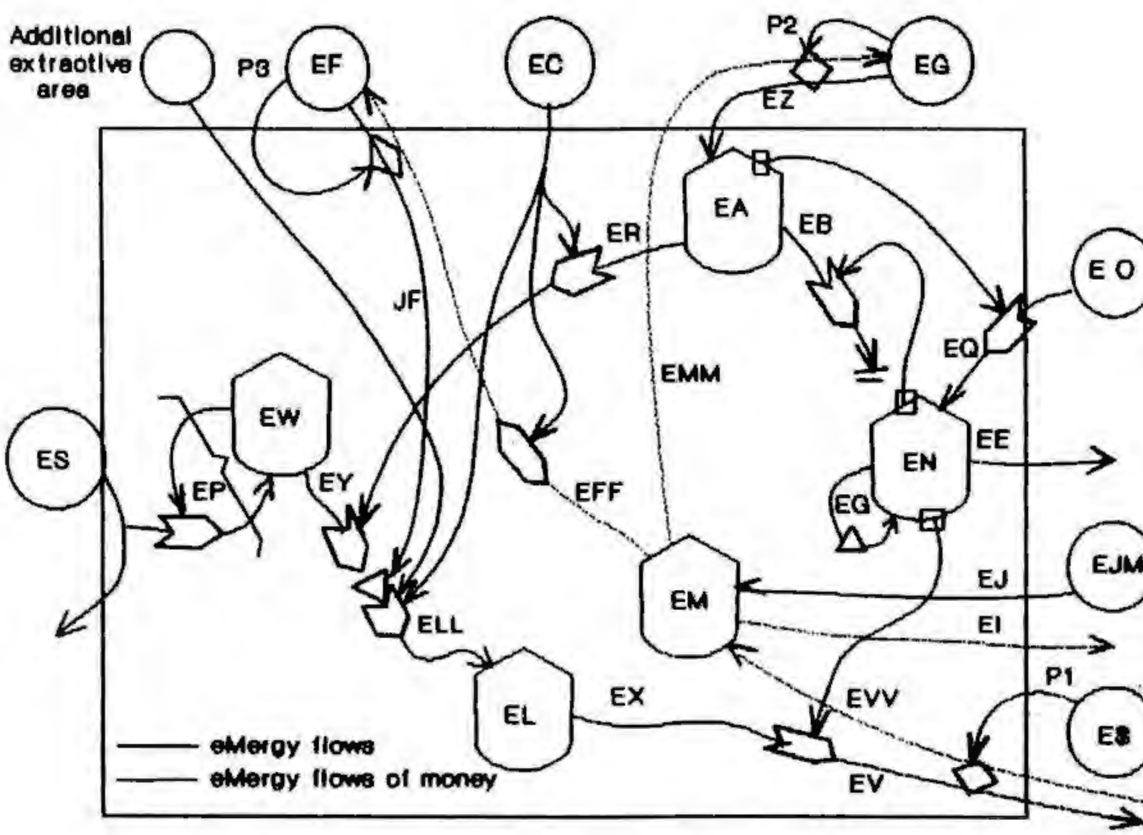


Figure 17 - eMergy simulation model

In Itacoatiara's case almost all money received from plywood sales exits the system and what stays within it just maintains industrial assets with few technological additions to industrial efficiency.

The model is based on rates of flow into and from five stocking components: forest timber biomass (W), industrial log stocks (L), Itacoatiara's population (N), its assets (A), and its money (M).

Calibration of the Model of Itacoatiara

Data was assembled for the five stocking components and the rates of flow into and from them. The coefficients were derived at steady state and their values used in the model's calculations.

Rate equations used for storage were:

For timber stock in forest (W):

$$DW = K1*R*W - K3*W*A/C - K2*W$$

Where: K1 = coefficient of net biomass growth in T/ha/yr
K2 = coefficient of biomass loss in T/ha/yr
K3 = flow of biomass to cutting in T/ha/yr

For stock of logs in Industrial Yards (L):

$$DL = K4*W*(A/C)*C - K5*L - K6*L*N$$

Where: K4 = coefficient of log flow in T/yr
K5 = coefficient of log losses in T/yr
K6 = coefficient of logs used in T/yr

For town's assets (A):

DA = K20*M/P2 - k9*A*N - k15*A*C*W - k18*A

Where: K9 = coefficient of flow of assets to population in $/yr
K15 = coefficient of flow of assets to timber cutting ($/yr).
K18 = coefficient of flow of assets depreciation in $/yr
K20 = coefficient of inflow of assets in $/yr

For money stock (M):

DM = P1*K7*L*N - K21*C*P3*JF - K14*M + JM - K19*M

Where: K7 = coefficient of flow of finished products and money return in $/yr
K14 = coefficient of incoming flow of money from product sales in $/yr
K19 = coefficient of outgoing flow of money from product sales in $/yr

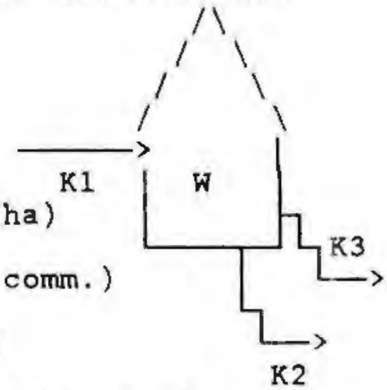
For population numbers (N):

DN = K10*N + K13*OP*A - K11*N - K12*N

Where: K10 = coefficient of population growth rate in people/yr
K11 = coefficient of population death rate in people/yr
K12 = coefficient of population emigrating in people/yr
K13 = coefficient of population immigrating in people/yr

Calculating coefficients (Flows per Year)

Coefficients were calculated according to the above equations and using assembled data on the magnitudes of the flows per year. Here 'Js' represent flows, and 'Ks' represent coefficients.



Forest timber stock (W)

Where:
- W = timber stock in forest (tons/ha) = 402 T/ha (tot.above & below ground - Fearnside, personal comm.)
- J1= net biomass growth (T/ha/yr) 1% of forest timber stock (W) = 402 x 0.01 = 4.02 T/ha
- J2= biomass lost in T/ha/yr (1% of biomass) 1% of forest timber stock (W) = 402 x 0.01 = 4.02 T/ha
- J3= flow of biomass to cutting (T/ha/yr) To calculate exploited area I considered 2 trees/ha and 2 m3/tree (R.W.Bruce, personal comm., 1993), a total of 4 m3/ha, for 100,000 m3/yr, we need 25,000 ha.

  100,000 m3 x 0.8 T/m3 = 80,000 T

  J3 = 80 E3 T/ha/yr x 2.5 (forest destruction factor, Uhl and Vieira, 1989; Fearnside, 1993) x 25,000 ha

  = 80 E3 T/ha/yr x 2.5/ 25,000 ha = 8 T/ha/yr

From equation 3, change in W = DW

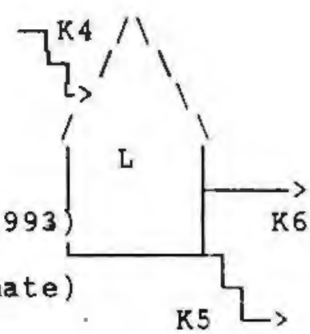
$$DW = K1*R*W - K3*W*A/C - K2*W$$

So: $J1 = K1*R*W$, $J2 = K2*W$, $J3 = K3*W*A/C$

$$K1 = J1/R*W = 4.02/(0.05*402)= 0.2$$
$$K2 = J2/W = 4.02/402 = 0.01$$
$$K3 = J3 / W*A/C = 8/[(402*1.6E8)/25000] = 3.11E-6$$

And: $K0*R*W = 0.95$

$$K0 = 0.95/(R*W) = 0.95/(0.05*402) = 0.054$$



Industrial stock of forest logs (L)

Where:
- J4 = flow of logs in tons/yr = (250000 m3/yr)(0.8 T/m3) = 200000 T/yr (R.W.Bruce,pers.comm.1993)
- J5 = log losses in Tons/yr (approximately 10% of J4, an estimate) = 20000 T/yr

J6 = logs used in tons/yr
(approx. 90% of J4)
= 180000 T/yr
L = stock of timber in tons
= 200000 T/yr (R.W.Bruce, personal comm., 1993)

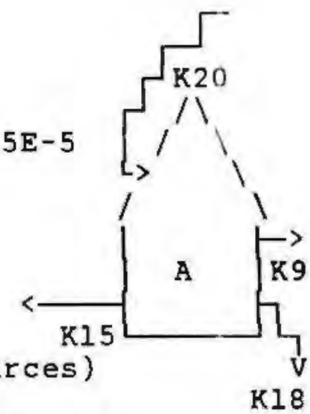
From equation 4, change in L = DL

DL = K4*W*(A/C)*C - K5*L - K6*L*N + 1.5*[K4*W*(A/C)*C]

So: J4 = K4*W*(A/C)*C, J6 = K6*L*N

Where: K4 = J4/[W*(A/C)*C]
= 200000/(402*1.6E8)
= 3.1E-6
K5 = J5/L
= 20000/200000
= 0.1
K6 = J6/(L*N)=180000/(200000*60000)= 1.5E-5

Assets of the town (A)



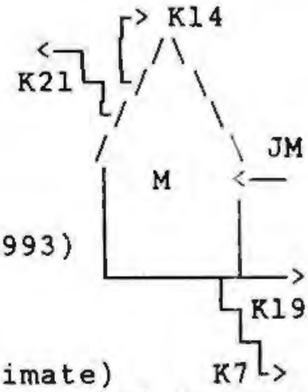
Where: A = town's assets in $
= 1.6 E8 $ (County Office & local sources)
J9= flow of assets to population ($/yr)
= 2.56 E6 $ (ICOTI - Survey of Itacoatiara)
J15= assets flowing to timber cutting activities ($/yr)
= 0.5E6 $
J18= depreciation ($/yr), 10%
= 1.6 E7 $
J20= incoming goods and services ($/yr)
= 3.16E6 $ (SEFAZ - 100 main commercial enterprises)

From equation 5, change in A = DA

DA = K20*M/P2 - K9*A*N - K15*A*C*W - K18*A

So: J9 = K9*A*N, J20 = K20*M/P2, J15 = K15*A*C*W, J18 = K18*A

And: K9 = J9/(A*N) = 2.5E6/(1.6E8*6E4) = 2.6E-7
K15 = J15/(A*C*W) = 0.5E6/(1.6E8*4.55E6*402) = 1.708E-12
K18 = J18/A = 1.6E7/1.6E8 = 0.1
K20 = (J20*P)/M = (3.16e6*0.3)/1.78E7 = 0.0532



Money stock (M)

Where: M = capital stock in industry \$
= 1.78E7 \$ (R.W.Bruce,pers.comm., 1993)
J7= flow of finished product and money return (\$)
= 1.78E7 \$
J14= goods and services for assets (estimate)
J19= money sent to Southern Brazil(approx.80%of income)
= 1.78E7 x 0.8 = 1.424E7 \$

From equation 6, change in M = DM

DM = P1*K7*L*N - K21*C*P3*JF - K14*M + JM

So: J7 = P1*K7*L*N, J14 = K14*M, JM is a constant, here assumed to be 1.

JF = K16*W*(A/C) and K16 = J16/[W*(A/C)]
K16= 1768.7 T/yr/(402*1.6E8/4.55E6) = 0.1251

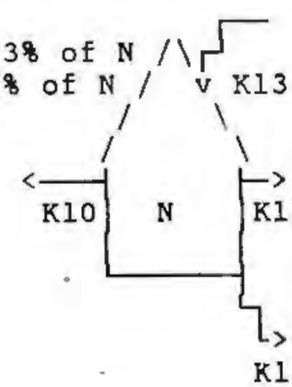
Therefore: JF = 0.1833*402*(1.6E8/4.55E6) = 2591.2

And: K7 = J7/(P1*L*N) = 1.78E7/(0.1*1.8E5*6E4)= 0.0165
K14= J14/M = 3.16E6/1.78E7 = 0.1775
K19= J19/M = 1.424E7/1.78E7 = 0.8

Also: K21*C*P3*JF = 4E5
K21 = 4E5/(C*P3*JF) = 4E5/(4.55E6*0.3*2591.2) = 1.13E-4

Population (N)

Where: N = population = 60000 people
J10 = population growth rate, approx. 3% of N
J11 = population death rate, approx. 2% of N
J12 = population emigrating, 1% of N
= 600 people/yr
J13 = population immigrating, 1% of N
= 600 people/yr



From equation 7, change in N = DN

DN = K10*N + K13*OP - K11*N - K12*N

So: J10 = K10*N, J11 = K11*N, J12 = K12*N, J13 = K13*OP

Where:
K10 = J10/N = 1800/60000 = 0.03
K11 = J11/N = 1200/60000 = 0.02
K12 = J12/N = 600/60000 = 0.01
K13 = J13/OP = 600/6000 = 0.1

Coefficient calculation is summarized in Table 11 using an electronic spreadsheet ('Excel 3.0' software). Table 12 shows the simulation program.

Table 11 - Calculating and calibrating coefficients

Model of Itacoatiara's Plywood Industry and Population

SOURCES	Symbol	Units
Natural Res.	I =	1
Deflected	R =	0.05
Area Used	C =	25000 Ha
Market Price	P1 =	0.1
Goods & Serv.	P2 =	0.3
Fuel Price	P3 =	1
Wood (Forest)	W =	402 kg/Ha
Assets (Town)	A =	1.60E+08 $
Logs (Stock)	L =	200000 Tons
Populatn.(nº)	N =	60000 People
Outside Popln	OP =	6000 People
Money	M =	4450000 $

COEFFICIENTS

Flow Equation	Value	Coefficient	Value
J0 = K0*R*W =	0.95	K0=	4.73E-02
J1 = K1*R*W =	4.02	K1=	2.00E-01
J2 = K2*W =	4.02	K2=	1.00E-02
J3 = K3*W*(A/C) =	8	K3=	3.11E-06
J4 = K4(A/C)C*W =	200000	K4=	3.11E-06
J5 = K5*L =	20000	K5=	1.00E-01
J6 = K6*L*N =	180000	K6=	1.50E-05
J7 = K7*L*N =	1.78E+07	K7=	1.48E-03
J9 = K9*A*N =	2.50E+06	K9=	2.60E-07
J10 = K10*N*A =	1800	K10=	3.00E-02
J11 = K11*N =	1200	K11=	2.00E-02
J12 = K12*N =	600	K12=	1.00E-02
J13 = K13*OP =	600	K13=	1.00E-01
J14 = K14*M =	3.16E+06	K14=	7.10E-01
J15 = K15*W*A*C =	500000	K15=	3.11E-10
J16 = K16*W*(A/C) =	1768.7	K16=	0.001
J18 = K18*A =	1.60E+07	K18=	0.10
J19 = K19*M =	1.42E+07	K19=	3.20E+00
J20 = K20*M/P2 =	3.16E+06	K20=	2.13E-01
J21 = K21*C*P3*JF =	4.00E+05	K21=	9.05E-03

```
'       Table 12
'
'
'       ITACOATIARA PLYWOOD INDUSTRY AND POPULATION MODEL
        energy calculations
CLS
SCREEN 1, 0: COLOR 0, 0
LINE (0, 0)-(319, 180), 3, B
LINE (0, 80)-(319, 180), 3, B
'
I = 1
R = .05
JM = 1
0 '        SCALING FACTORS
0 '
0 DT = .1
0 TO = .1
0 WO = 10
0 AO = 2000000
0 MO = 100000
0 NO = 10000
0 LO = 20000
0 '                INITIAL STORAGE QUANTITIES
0 '
0 C = 25000!:       ' land area  Ha
0 W = 402!:         ' Ton/Ha
0 A = 1.6E+08:      ' assets - $
0 M = 4450000!      ' money pool
0 N = 60000!:       ' population nos.
0 L = 200000!:      ' tons
0 '
0 P1 = .1           ' price for finished plywood product
0 P2 = .3           ' price for incoming goods and services
0 P3 = 1            ' fuel price
0 F = 1:            ' tons
0 OP = 6000!        ' people
0 G = 3000!         ' goods & services
0 '
0 '        COEFFICIENTS
0 '
0 K0 = .0473:              ' energy entering in forest system
0 K1 = .2:                 ' energy entering in wood storage
0 K2 = .01:                ' energy lost by wood storage
0 K3 = .00000311#: :       ' energy entering multiplier
0 K4 = 3.11E-06:           ' energy entering LOG stock
0 K5 = .1:                 ' log storage depreciation
0 K6 = .000015             ' energy entering town multiplier
0 K7 = .00148:             ' processed timber to outside markets
0 K8 = 0:                  ' money depreciation
0 K9 = 2.6E-07:            ' aasets to multiplier
0 K10 = .03:               ' population birth rate
0 K11 = .02:               ' population death rate
0 K12 = .01:               ' population emigrating
0 K13 = .1:                ' outside population pressure
0 K14 = .71:               ' goods & services to assets
0 K15 = 3.11E-10:          ' assets to cutting
5 K16 = .001:              ' fuel to cutting
6 K18 = .1:                ' assets depreciation
0 K19 = 3.2:               ' MONEY TO SOUTH
0 K20 = .213:              ' inflow of aasets
5 K21 = .00905:            ' outflow of dollars to purchased fuels
```

Table 12 (continued)

```
'
'       SETTING COMPONENTS GRAPHICS
'
PSET (T / TO, 80 - L / LO), 3:      ' sawn timber stock    YELLOW
PSET (T / TO, 180 - A / AO), 1:     ' ASSETS               GREEN
PSET (T / TO, 180 - M / MO), 2:     ' money pool           RED
PSET (T / TO, 180 - N / NO), 3:     ' population numbers   BROWN
PSET (T / TO, 80 - W / WO), 1:      ' wood                 GREEN
'
'       EQUATIONS
R = I / (1 + KO * W)
JF = K16 * W * (A / C)
DW = K1 * R * W - K3 * W * A / C - K2 * W
DL = K4 * W * (A / C) * C + 1.5 * (K4 * W * (A / C) * C) - K5 * L - K6 *
DA = K20 * M / P2 - K9 * A * N - K15 * A * C * W - K18 * A
DM = P1 * K7 * L * N - K21 * C * P3 * JF - K14 * M + JM - K19 * M
DN = K10 * N + K13 * OP - K11 * N - K12 * N
W = W + DW * DT
IF W < 0 THEN W = 0
A = A + DA * DT
IF A < 0 THEN A = 0
M = M + DM * DT
IF M < 0 THEN M = 0
IF M > 3.2E+07 THEN M = 3.2E+07
L = L + DL * DT
IF L < 0 THEN L = 0
N = N + DN * DT
IF N < 0 THEN N = 0
'
'        REITERATIONS
'
'PRINT R
T = T + DT
IF T / TO < 319 GOTO 590
```

Simulation Results using energy flows

General patterns

Assuming available data for system components are correct, the model describes the situation of a "boom and bust" economy. Figure 18 graphs W (Forest Wood Stock), L (Logs Stock), in the top frame, and A (Town's Assets), M (Money), N (Population Numbers) in the bottom one, for a 32 year period; Table 13 summerizes results for different time periods.

In the first 2 years the stock of logs rises (392,646 Tons, for L at 2 years, Table 13), followed by a high in capital returns ($ 790,300, for M at 2 years, table 13). This lowers considerably forest timber stock (from 402 t/ha, above and below ground biomass, to 387.96 t/ha, W for 2 years, Table 13) which reaches its lowest after 32 years of exploitation (351.77 t/ha, W, Table 13) and then starts to recover due to natural regrowth and the lack of assets for investment in extractive activities.

Also, as depreciation of assets brings assets down at a rate of 10% per year, the stock of logs dwindles, diminishing by more than 30% between the 4th and the 8th year, by 2/3 between the 8th and the 16th year, reaching 9,058 tons after 32 years (Table 13).

Money decreases sharply from an initial value of $ 4.5 million

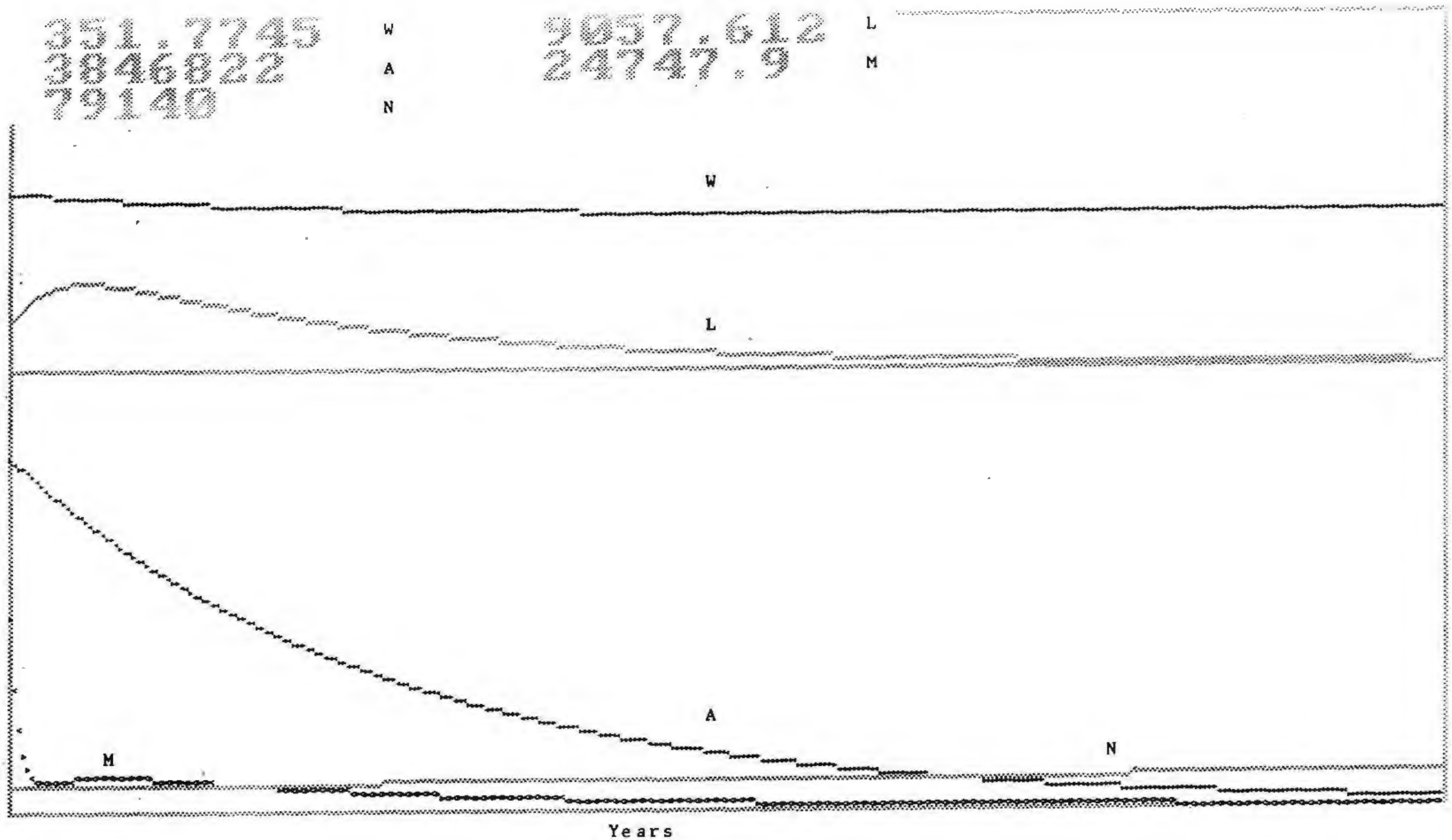


Figure 18 - Energy simulation results.

Table 13 - Energy simulation results.

Time Factor (Years)		**1**	**2**	**4**	**8**	**16**	**32**	**48**	**64**	**80**
TO		**0.003125**	**0.00625**	**0.0125**	**0.025**	**0.05**	**0.1**	**0.15**	**0.2**	**0.25**
W	Forest Wood StocK - Ton/ha	394.47	387.96	377.42	363.58	352.09	351.77	357.67	363.69	368.98
L	Log Stock - Ton/yr	372775	392646	325446	191972	67811	9058	1189	152	19
A	Town's Assets - $	1.430E+08	1.274E+08	1.012E+08	6.384E+07	2.519E+07	3.847E+06	5.577E+05	7.769E+04	1.053E+04
M	Money Stock - $	6.868E+05	7.903E+05	6.996E+05	4.307E+05	1.631E+05	2.475E+04	3.65E+03	516	71
N	Number of People	60600	61200	62400	64800	69600	79140	88740	98340	107880

to $ 686,800 after the first year, rises to its peak after 2 years at $ 790,300, and then tapers off, never to recover ($ 71 after 80 years, M, Table 13).

Population rises evenly due to constant rates of birth, death, emigration and immigration.

Altering present flow rates

Outside population pressure

A five fold increase in population pressure (coefficient K13 goes from 0.1 to 0.5 - Table 14) has a negative effect on money (M goes from $ 24,748 to $ 18,250 - Table 14) and assets (A goes from $ 3.847 million to $ 2.8 million). This reduces log stock by a third (L, from 9,058 tons to 3,376 tons) and has a lesser impact on forest wood stock (W goes from 351.77 t/ha to 353.37 t/ha). The result is an increasingly impoverished population. Increasing population pressure ten-fold and twenty-fold has, proportionally, the same effects.

Population emigrating

A decrease in population, caused by twice the emigration rate (the emigration coefficient K12 goes from 0.01 to 0.02), results in greater availability of assets and money ($ 5.485 million and $ 27,612, respectively, Table 14) which increases log stock (12,816

Table 14 - Energy Simulation Results

Outside Population Pressure

k13	N	W	L	A	M
0.1	79140	351.77	9058	3.847E+06	24748
0.5	155700	353.37	3376	2.800E+06	18250
1	251400	355.15	1407	1.877E+06	12358
2	442800	358.09	360	8.414E+05	5646

Population Emigrating

k12	N	W	L	A	M
0.01	79140	351.77	9058	3.847E+06	24748
0.02	60000	351.35	12816	4.161E+06	26489
0.1	9649	349.19	85833	5.485E+06	27612
1	606	347.18	466389	5.893E+06	6046

Population Birth Rate

k10	N	W	L	A	M
0.03	79140	351.77	9058	3.847E+06	24748
0.015	52390	351.15	15095	4.303E+06	27210
0	35340	350.62	23746	4.670E+06	28761

Fuel Price

P3	N	W	L	A	M
1	79140	351.77	9058	3.847E+06	24748
2	79140	352.01	8894	3.773E+06	21137
4	79140	352.47	8576	3.629E+06	14284
8	79140	353.33	7980	3.362E+06	1971
0.5	79140	351.66	9140	3.884E+06	26601
0.25	79140	351.6	9182	3.903E+06	27539
0.1	79140	351.56	9207	3.914E+06	28106

Land Area (Ha)

C	N	W	L	A	M
25000	79140	351.77	9058	3.847E+06	24748
50000	79140	376.45	8867	3.509E+06	24257
100000	79140	389.55	7581	2.884E+06	20789
200000	79140	396.23	5228	1.934E+06	14402
10000	79140	288.86	7707	3.994E+06	21037
5000	79140	212.69	5611	3.959E+06	15301
1000	79140	42.63	1024	3.722E+06	2755

Plywood Price ($)

P1	N	W	L	A	M
0.1	79140	351.77	9058	3.847E+06	24748
0.2	79140	349.83	10556	4.528E+06	61351
0.4	79140	345.6	14198	6.216E+06	169628
1	79140	329.77	31942	1.498E+07	964463
10	79140	219.72	252256	1.866E+08	3.20E+07
0.05	79140	352.71	8380	3.542E+06	9967
0.01	79140	353.4	7888	3.321E+06	0

tons, from the original 9,058 tons, for 32 years, Table 14) and slightly lowers forest wood stock (from 351.77 to 351.35 t/ha). This trend is confirmed with a greater number of people emigrating (K12 = 0.1). The unlikely hypothesis of all the population emigrating (K12 = 1), leaving just 606 people, reduces the town to a camp where only workers live, functioning as a minimal timber extracting and processing unit. Assets are high, money is almost gone, but the log stock has reached an all-time high of 466,380 tons, and forest timber stock its lowest ever, at 347.18 t/ha.

Population birth rate

A lower population birth rate has the same effect as greater emigration, increasing assets and capital, increasing log stock, and decreasing forest timber stock (Table 14, K10 - Population birth rate).

Fuel price

A rise in fuel prices decreases assets and capital, lowers wood stock and increases forest wood stock. A fall in fuel prices has the opposite effect, although forest wood stock stabilizes around 351.5 T/ha (Table 14 - P3: Fuel price).

Plywood price

As expected, increasing the price paid for plywood by outside markets increases assets, capital and log stocks, greatly decreasing forest wood stock. A decrease in price has the opposite effect (Table 14 - P1: Plywood price).

Land area

An increase in the area of exploited land means that industry loses assets and money because of transport and infrastructure costs. It also means smaller log stocks and a smaller impact on forest wood stock. A decrease in area produces more assets and money, greater log stocks and greater impact on forest wood stock (Table 14 - C: Land area).

Simulation model using eMergy flows

Transformities and eMergies can be calculated within a macroscopic minimodel by adding suitable equations. Values for eMergies can be graphed like other variables. The model calculates these values on the basis of matter and/or energy flows and storages (Odum and Odum, 1989). An eMergy model cannot be calibrated on the basis of eMergy as only energy or matter follow the laws of matter and energy conservation where inflowing matter or energy must equal that stored and outflowing. EMergy is, however, a tabulation of what was processed in making the product and is not reduced by the necessary dispersal of energy or by product matter (Odum and Odum, 1989). EMergy can be tallied for each component storage and transformities calculated by computing eMergy at each step of the simulation. In the model desognations for eMergy flows start with E (i.e.: ES, EP, EY, etc.) and designations for solar transformities start with TR (i.e.: TRS, TRP, TRY, etc.).

As the Itacoatiara model has already been calibrated for simulation in units of joules and matter, equations for eMergy calculation were added. Transformities were multiplied by their respective flows. The eMergy in each storage is the integrated sum of the input eMergy flows minus outflows. Energy dispersal and depreciation, both essential within the system, do not detract from eMergy. When an eMergy storage is not applied to more transformations, and is not useful, there is a loss in eMergy through energy dispersal and depreciation of that storage. When a storage is an essential part of the next step of transformation its eMergy is transmitted forward with a higher transformity caused by the dispersal and degrading necessary to the transformation process. As more eMergy values are added in, transformities increase. On each iteration the transformity of a stored quantity is calculated by dividing the eMergy tally for that storage by its energy storage.

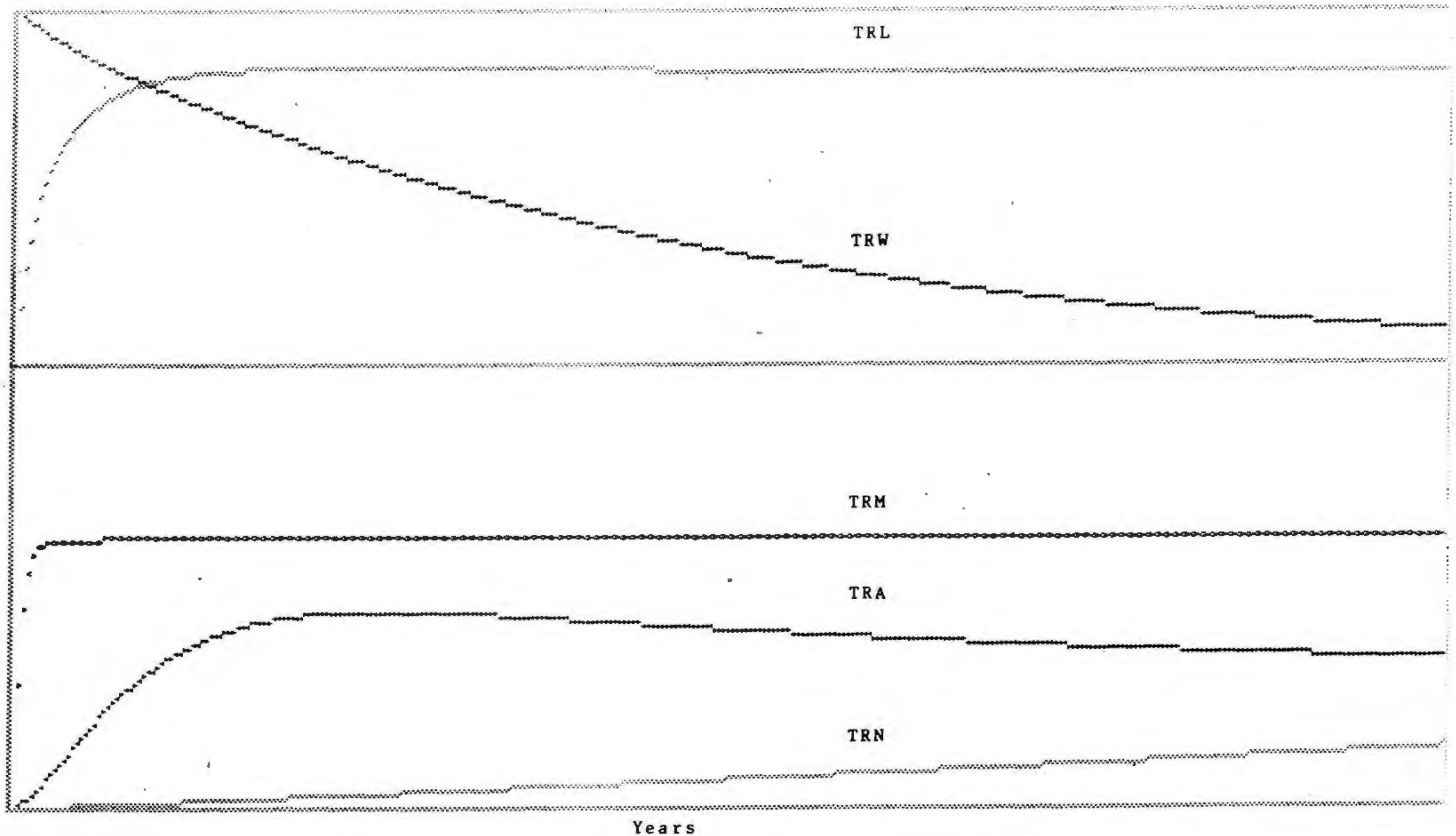


Figure 19 - eMergy simulation results.

```
10 '        Table 15
16 '
20 '        ITACOATIARA'S PLYWOOD INDUSTRY AND POPULATION MODEL
26 '        eMergy calculations
29 '
30 CLS
40 SCREEN 1, 0: COLOR 0, 0
50 LINE (0, 0)-(319, 180), 3, B
55 LINE (0, 80)-(319, 180), 3, B
60 '
70 I = 1
80 R = .1
90 JM = 1
100 '          SCALING FACTORS
110 '
120 DT = .1
130 TO = .1
150 WO = 10
160 AO = 2000000
170 MO = 1000000
180 NO = 10000
190 LO = 20000
200 TRWO = 100000
210 TRLO = 10000000
220 TRAO = 10000#
230 TRMO = 100000000000#
240 TRNO = 100000#
250 '
270 '          INITIAL STORAGE QUANTITIES
290 '
300 C = 25000!:            ' land area  Ha
310 W = 402!:              ' Ton/Ha
320 A = 1.6E+08:           ' assets - $
330 M = 4450000!           ' money pool
340 N = 60000!:            ' population nos.
350 L = 200000!:           ' tons
360 '
370 P1 = .1                ' price of finished plywood product
380 P2 = .3                ' price of incoming goods & services
390 P3 = 1                 ' fuel price
400 F = 1:                 ' tons
410 OP = 6000!             ' people
420 G = 3000!              ' goods & services
430 '
440 '          TRANSFORMITIES
450 '
460 TRS = 1
470 TRY = 4E+08
480 TRG = 4030000!
490 TRJ = 6.08E+12
500 TRVV = 6.08E+12
510 TROP = 4030000!
520 TRLL = 6E+08
530 TRW = 4E+08
532 '
550 '         COEFFICIENTS
560 '
570 K0 = .0473:            ' energy entering in forest system
580 K1 = .2:               ' energy entering in wood storage
590 K2 = .01:              ' energy lost by wood storage
600 K3 = .00000311#:       ' energy entering multiplier
610 K4 = .00000311#:       ' energy entering LOG stock
620 K5 = .1:               ' log storage depreciation
630 K6 = .000015           ' energy entering town multiplier
640 K7 = .0148:            ' processed timber to outside markets
650 K8 = 0:                ' money depreciation
660 K9 = 2.6E-07:          ' assets to multiplier
670 K10 = .03:             ' population birth rate
680 K11 = .02:             ' population death rate
690 K12 = .01:             ' population emigrating
700 K13 = .1:              ' outside population pressure
710 K14 = .71:             ' goods & services to assets
720 K15 = 3.11E-10:        ' assets to cutting
730 K16 = .001:            ' fuel to cutting
740 K18 = .1:              ' assets depreciation
750 K19 = 3.2:             ' MONEY TO SOUTH
760 K20 = .213:            ' inflow of assets
770 K21 = .00905:          ' outflow of dollars to purchased fuels
```

```
780 '       Table 15 (continued)
790 '
800 '       SETTING COMPONENTS GRAPHICS
810 '
820  PSET (T / T0, 80 - TRL / TRL0), 3:    ' sawn timber stock     YELLOW
830  PSET (T / T0, 180 - TRA / TRA0), 1:   ' assets                GREEN
840  PSET (T / T0, 180 - TRM / TRM0), 2:   ' money pool            RED
850  PSET (T / T0, 180 - TRN / TRN0), 3:   ' population numbers    BROWN
860  PSET (T / T0, 80 - TRW / TRW0), 1:    ' wood                  GREEN
870 '
880 '       EQUATIONS
890 '
900 R = I / (1 + K0 * W)
910 JP = K16 * W * (A / C)
920 DW = K1 * R * W - K3 * W * A / C - K2 * W
930 DEW = EP - EY
940 EW = EW + DEW * DT
950 TRW = EW / W
960 DL = K4 * W * (A / C) * C + 1.5 * (K4 * W * (A / C) * C) - K5 * L - K6 *
 N
970 DEL = ELL - EX
980 EL = EL + DEL * DT
990 TRL = EL / L
1000 DA = K20 * M / P2 - K9 * A * N - K15 * A * C * W - K18 * A
1010 DEA = EZ - EB - ER
1020 EA = EA + DEA * DT
1030 TRA = EA / A
1040 DM = P1 * K7 * L * N - K21 * C * P3 * JP - K14 * M + JM - K19 * M
1050 DEM = EJ + EVV - EI - EMM - EFF
1060 EM = EM + DEM * DT
1070 TRM = EM / M
1090 DN = K10 * N + K13 * OP - K11 * N - K12 * N
1100 DEN = EQ + EG - EE
1110 EN = EN + DEN * DT
1120 TRN = EN / N
1130 W = W + DW * DT
1140 IF W < 0 THEN W = 0
1150 A = A + DA * DT
1160 IF A < 0 THEN A = 0
1170 M = M + DM * DT
1180 IF M < 0 THEN M = 0
1190 IF M > 3.2E+07 THEN M = 3.2E+07
1200 L = L + DL * DT
1210 IF L < 0 THEN L = 0
1220 N = N + DN * DT
1230 IF N < 0 THEN N = 0
1240 ES = TRS * (K0 * R * W)
1250 EP = TRP * (K1 * R * W)
1255 EY = TRW * (K3 * W)
1260 EW = TRY * (K3 * W * A / C)
1265 TRP = ES / (K1 * R * W)
1270 ELL = TRLL * ((K4 * W * (A / C) * C) + (1.5 * (K4 * W * (A / C) * C)))
1280 EX = TRL * (K6 * L * N)
1290 EV = TRL * (K7 * P1 * L * N)
1300 EE = TRN * (K12 * N)
1310 EG = TRN * (K10 * N)
1320 EB = TRA * (K9 * A * N)
1340 EZ = TRG * (K20 * M / P2)
1350 ER = TRA * (K15 * A * C * N)
1360 EJ = TRJ * (JM)
1370 EI = TRM * (K19 * M)
1380 EFF = TRM * (K21 * C * P3 * JP)
1390 EMM = TRM * (K14 * M)
1400 EVV = TRVV * (P1 * K7 * L * N)
1410 EQ = TROP * (K13 * OP)
1420 '
1450 '       REITERATIONS
1460 '
1470 T = T + DT
1480 IF T / T0 < 319 GOTO 820
```

Simulation Results for eMergy Flows

General Patterns

As forest wood stock is depleted wood stock storage transformity gradually declines (from 7.321 E6 sej/J at year 1, to 1.615 E4 sej/J at year 80 - Table 16). Log transformity reaches a maximum at the eighth year (TRL of 6.689 E8 sej/J - Table 16), lagging behind the peak log stock which happens between 2 and 4 years (L=372.775 and 392.46 Ton/ha respectively - Table 13), and then stabilizes around 6.6 E8 sej/J, to start falling slightly to 6.396 E8 sej/J after 80 years.

Assets transformity peaks at the eighth year (TRA of 4.432 E5 sej/J - Table 16), accompanying log transformity and then decreases as assets are depreciating (10% per year). Population transformity rises due to population increase.

The most important result is the marked loss in forest wood stock transformity.

Table 16 - eMergy simulation results.

Time Factor (Years)	1	2	4	8	16	32	48	64	80
TO	0.003125	0.00625	0.0125	0.025	0.05	0.1	0.15	0.2	0.25
TRW Forest Wood StocK Transformit	7.321E+06	6.780E+06	5.908E+06	4.488E+06	2.520E+06	7.512E+05	2.133E+05	5.909E+04	1.615E+04
TRL Log Stock Transformity	4.790E+08	5.904E+08	6.552E+08	6.689E+08	6.639E+08	6.553E+08	6.488E+08	6.437E+08	6.396E+08
TRA Town's Assets Transformity	8.830E+04	2.050E+05	3.644E+05	4.432E+05	4.028E+05	3.355E+05	2.986E+05	2.728E+05	2.524E+05
TRM Money Stock Transformity	5.994E+12	6.050E+12	6.077E+12	6.080E+12	6.080E+12	6.080E+12	6.08E+12	6.08E+12	6.08042E+12
TRN Number of People Transformity	3.62E+04	6.650E+04	1.572E+05	3.193E+05	6.502E+05	1.358E+06	2.181E+06	3.173E+06	4.394E+06

Altering Present Flow Rates

Outside population pressure - An increase in outside population pressure lowers all but money and population transformities. Doubling population inflow decreases forest wood stock transformity from 7.512 E5 to 5.714 E5 sej/J, log stock transformity from 6.553 E8 to 6.276 E8 sej/J and assets transformity, with a reduction of 50 %, from 3.355 E5 to 1.677E5 sej/J (Table 17). Money transformity slightly increases from 6.8037 E12 to 6.08065 E12 sej/$, and population transformity from 1.358 E6 to 3.456 E6 sej/J (Table 17). A further increase in population pressure (K13 of 1 and 2) gives the same results.

Population emigrating - Emigration has an effect opposite to that of population inflow. All transformities increase with the exception of money transformity which decreases slightly (from 6.0837 E12 sej/$ with 1% population emigrating, for K12 = 0.01, to 6.0778 E12 sej/$, for K12 = 1 - Table 17).

With 10% of the population emigrating, forest wood transformity rises to 8.267 E5 sej/J, log stock transformity almost doubles to 1.021 E9 sej/J and assets transformity shoots up by almost one order of magnitude to 2.484 E6 sej/J. Money transformity declines very slightly, from 6.08033 E12 to 6.08023 E12 sej/$.

Table 17 - eMergy Simulation Results

Outside Population Pressure

k13	TRW	TRL	TRA	TRM	TRN
0.1	7.512E+05	6.553E+08	3.355E+05	6.0804E+12	1.358E+06
0.5	5.714E+05	6.276E+08	1.677E+05	6.0807E+12	3.456E+06
1	3.952E+05	6.170E+08	1.036E+05	6.0812E+12	4.285E+06
2	1.848E+05	6.097E+08	5.969E+04	6.0828E+12	4.868E+06

Population Emigrating

k12	TRW	TRL	TRA	TRM	TRN
0.01	7.512E+05	6.553E+08	3.355E+05	6.0804E+12	1.358E+06
0.02	7.965E+05	6.731E+08	4.432E+05	6.0803E+12	1.507E+06
0.1	8.267E+05	1.021E+09	2.484E+06	6.0802E+12	3.198E+06
1	3.717E+05	3.923E+09	5.416E+06	6.0778E+12	4.113E+06

Population Birth Rate

k10	TRW	TRL	TRA	TRM	TRN
0.03	7.512E+05	6.553E+08	3.355E+05	6.0804E+12	1.358E+06
0.015	8.147E+05	6.837E+08	5.075E+05	6.0803E+12	1.590E+06
0	8.524E+05	7.236E+08	7.486E+05	6.0803E+12	1.863E+06

Fuel Price

P3	TRW	TRL	TRA	TRM	TRN
1	7.512E+05	6.553E+08	3.355E+05	6.0804E+12	1.358E+06
2	7.387E+05	6.553E+08	3.322E+05	6.0798E+12	1.358E+06
4	7.143E+05	6.554E+08	3.258E+05	6.0786E+12	1.358E+06
8	6.676E+05	6.555E+08	3.127E+05	6.0762E+12	1.358E+06
0.5	7.575E+05	6.553E+08	3.371E+05	6.0807E+12	1.358E+06
0.25	7.607E+05	6.553E+08	3.379E+05	6.0808E+12	1.358E+06
0.01	7.626E+05	6.553E+08	3.383E+05	6.0809E+12	1.358E+06

Plywood Price ($)

P1	TRW	TRL	TRA	TRM	TRN
0.1	7.512E+05	6.553E+08	3.355E+05	6.0804E+12	1.358E+06
0.2	2.576E+06	6.535E+08	5.441E+05	6.0802E+12	1.358E+06
0.4	9.197E+06	6.520E+08	7.644E+05	6.0798E+12	1.358E+06
1	9.285E+06	6.520E+08	7.812E+05	1.4373E+12	1.358E+06
10	9.286E+06	6.520E+08	7.812E+05	1.4366E+12	1.358E+06
0.05	3.644E+05	6.566E+08	1.840E+05	6.0801E+12	1.358E+06
0.01	1.937E+05	6.580E+08	3.631E+04	6.0736E+12	1.358E+06

Land Area (Ha)

C	TRW	TRL	TRA	TRM	TRN
25000	7.512E+05	6.553E+08	3.355E+05	6.0838E+12	1.358E+06
50000	3.794E+05	6.552E+08	1.740E+05	6.0834E+12	1.358E+06
100000	1.667E+05	6.554E+08	8.964E+04	6.0804E+12	1.358E+06
200000	5.865E+04	6.560E+08	4.601E+04	6.0806E+12	1.358E+06
10000	1.536E+06	6.558E+08	8.467E+05	6.0806E+12	1.358E+06
5000	2.315E+06	6.562E+08	2.043E+06	6.0807E+12	1.358E+06
1000	5.772E+06	6.545E+08	6.038E+06	6.0801E+12	1.358E+06

When all population emigrates, leaving just 606 people (see Population emigrating in Table 14), assets are high and little used by the population, and they are all used to greatly increase log stock (a high transformity of 7.236 E8 sej/J - Table 17) causing great depletion of natural resources (forest wood stock transformity, TRW, reaches a low of 3.717 E5 sej/J - Table 17). Population transformity stabilizes at 4.113 E6 sej/J.

Population birth rate - A decrease in population birth rate has an effect similar to that of population emigrating, although with much smaller increases in transformities. The transformity for money continues to decrease slightly, one needs more money to buy less value (Table 17). With less population there's greater log stock, which remains accumulated for longer times, lowering depletion of forest wood stock, thus increasing its transformity (from 7.512 E5 sej/J, for 3% population birth rate, K10 = 0.03, to 8.524 E5 sej/J, for no population birth rate, K10 = 0 - Table 17).

Fuel price - An eight fold increase in fuel price lowers assets transformity from the original 3.355 E5 sej/J to 3.127 E5 sej/J (Table 17), slightly increases log stock transformity, from 6.553 E8 to 6.555 E8 sej/J (Table 17), due to higher extraction costs, and lowers money transformity, from 6.0837 E12 to 6.0762 E12 sej/$. Population transformity is unaffected. Forest wood stock transformity is lowered, from 7.512 E5 to 6.676 E5 sej/J, due to the still high extraction rates. In general, lowering fuel prices doesn't have such a great effect on transformities (see Table 17 for fuel prices, P3, of 0.5, 0.25, 0.1).

Plywood price - Increasing plywood prices greatly increases assets transformity (3.355 E5 to 7.644 E sej/\$, for a 4 fold price increase, P1, from 0.1 to 0.4 - Table 17). This increase is accompanied by a greater initial increase in money transformity which the drops to a lower value than the original one (from 6.0937 E12 sej/\$, with P1 = 0.1, to 6.0797 E12 sej/\$, with P1 = 0.4 - Table 17). These peak increases in money and assets cause an increase in forest wood stock transformity (from 7.512 E5 for original plywood price to 9.197 E6 sej/J for a 4 fold price increase - Table 17). Log stock decreases in transformity (6.553 E8 to 6.52 E8 sej/J) because of higher assets and money transformities. Population transformity is not affected. Lowering plywood prices has the opposite effect.

Land area - Increasing exploited land area increases log stock transformity (6.553 E8 to 6.560 E8 sej/J for an eight fold increase in exploited land area - Table 17), greatly reduces assets transformity (3.355 E6 to 4.601 E4 sej/J for the same increase), lowers money transformity, and greatly reduces forest wood stock transformity (7.512 E5 to 5.865 E4 sej/J). Reducing exploited land has the opposite effect.

CONCLUSIONS AND RECOMMENDATIONS

In the discussion section it was seen that Brazil had a net Emergy loss from trade, and a very low investment ratio compared to other countries. It thus still has a chance to learn from the mistakes of other nations, and, with the help of improved evaluation methods, balance development with a durable use of its natural resources.

Brazil is also a 'resource provider'. Its net eMergy loss from trade is not directly due to the deficit in its balance of payments, but rather to the fact that much value is exported in mining, timber and agricultural products. Brazil has to review its commercial terms of payment and product prices, putting pressure on international markets for fairer deals, and assuming, at the same time, the moral obligation to repay nature's contributions.

In Itacoatiara urbanization rate and population increase were great due to the installation of the plywood industry. Here industry had a great advantage on other Brazilian regions as eMergy/money value was 2.18 times greater than that of the rest of Brazil, meaning that, for US $ 1.00 invested in Itacoatiara, industry got twice the eMergy result as compared to industries elsewhere in the country (see page 71). At the same time, virtually all benefits flowed out of the town's boundaries, and companies did not invest sufficiently back into the town's structure.

The use of the eMergy Investment Ratio as an indicator of the intensity of development shows that Investment Ratio for logging is already 10 times that of Brazil as a whole (0.64/1 as against 0.064/1, Table 3, line 22). The eMergy Investment Ratio gets higher for the finished product, almost 24 times that of Brazil, and, if we consider the whole town as the structure necessary for the existence of industry, jumps to 364.37/1. As this is around 50 times the average for United States, it is an indication that assigning the full assets of the town to industry doesn't hold. Although the town's structure houses industry and provides labor, it cannot be claimed that industry, by itself, is responsible for the town. Thus the production process for plywood cannot be seen as using all of the town's assets for its functioning. If, however, a proportional share of all eMergy use by the town is assigned to support industry, eMergy calculations confirm this supportive relationship. Results show that 24% of the town's eMergy economy is represented by industry (page 71), this proportion could be added to industry's emergy use as the town's contribution to its functioning. In Table 18, calculations of the Net eMergy Yield Ratio and of the eMergy Investment Ratio, resulting from the addition of 24% of the town's eMergy use to industry, confirm this finding. The Net eMergy Yield Ratio for industry remains the same: 1.65/1 (0.01 inferior to the one calculated in Table 7, Section CC', 1.66/1), which means that 24% is the actual proportion of the town's eMergy contribution to industry; while the eMergy Investment ratio is 1.65 times higher

Table 18 ' Additional 24% of town´s eMergy use to industry

	Solar eMergy (E18 sej/yr)	24% of all used eMergy
Total town´s environmental eMergy contribution (I, Table 8)	1.05	0.25
Total industry environmental eMergy contribution (I, Table 7)	93.77	
Total town´s eMergy contribution (F, Table 8)	383.36	92.01
Total industry´s eMergy contribution (F, Table 7)	141.78	
Total environmental eMergy received by industry (I)	94.02	
Total eMergy contributed by industry and town (F t)	233.79	
RATIOS		
Net eMergy Yield Ratio = Y / F t = 384.93 E18 sej/yr (Y, Table 7) / 233.79 E18 sej/yr =	1.646	
eMergy Investment Ratio = F t / I = 233.79 E18 sej/yr/94.02 E18 sej/yr =	2.487	

(2.487/1, Table 18, as against the original of 1.51, Table 7), as input eMergies (F) have been increased by the town. Remembering that the Net eMergy Yield Ratio is the yielded eMergy divided by the eMergy feedback from the economy, it is a useful index for considering whether a source is a primary source capable of supporting more of the economy than itself. Odum's findings show that nonrenewable fuels such as coal, oil, natural gas yielded 6 times more than what was required for mining and processing. Very high Net eMergy Yield Ratios are obtained when forests are harvested without any effort at replanting (as high or higher than the fossil fuels). Also (Odum, 1991, unpublished paper) sustainable forest production has lower eMergy Investment Ratios, between 1.1 and 5. Greater Net eMergy Yields require longer growing cycles relative to planting efforts. The more intensive forest production efforts (more purchased inputs (F)), the lower the Net eMergy Yield Ratio. My results show that the relative lower Net eMergy Yield Ratio for varzea logs FOB industry, of 2.56/1, is due not to a more sustainable form of extraction, but to the high várzea productivity, which lowers the logs initial transformity (1.7 E4 sej/J, Table 5) and consequently the yield (Y), which is the numerator of the Net eMergy Yield Ratio (Y/F).

In the comparison of log felling and transport eMergies to dollars paid FOB Itacoatiara, it was estimated that eMergy expenditures for log felling and transport were 12.25 times greater than what was paid for logs FOB Itacoatiara. In 1989, the average export price for one cubic meter of timber in logs was US$ 9.48, while the same log would be paid at least twice FOB industry in the state of Amazonas (Hummel et al., 1993, p.39). Price per cubic meter of log in Itacoatiara was of US$ 24.00. EMergy expenditures would reach 31 times the eMergy to dollar value if the price FOB Itacoatiara for international export of logs were to be considered. Even though very general and approximate figures were used for quantifying the processes involved, a difference of this magnitude clearly reflects the inability of money to serve as a true measure of energy expenditure and of real costs. Provided guarantees could be offered assuring that revenues would be used to sustain the forest resource, this result strengthens the case for higher prices for exported raw materials to industrialized countries. After centuries of exploitation it is time to consider returning resources for the sake of conservation and more meaningful development.

" A reasonable management of world tropical forests requires their use to be organized in sustainable cycles to maximize the eMergy use of national and regional systems in which they are embedded, contributing more to the world economy in the long run than left to the excess of market economies." (Odum, 1991, unpublished paper, p.50).

Itacoatiara represents a typical 'boom and bust' export economy. At least up to 1992 there seemed to be no concern for restocking natural resources or managing varzea forest. Revenues are not stocked or recycled locally and minimal investments are made just to keep industry afloat with novel plywood processing technology. There is no attempt to benefit local population as an outcome of industrial processes.

Much work needs to be done with industry at a national and international level to educate it to put back into the environment a certain fraction of its net income. This is especially so now, when the emerging trend is one of entering varzea forest with heavy tractors and transporting logs out with barges, as demand is growing and traditional varzea areas in the Rio Madeira are practically depleted of species useful to plywood industry.

As already pointed out in the introduction, there already exists a Federal Fund for reposition of forest stocks, and, according to federal legislation, for each cubic meter of extracted timber a minimum of 6 trees must be planted. This has not been obeyed. During the last 40 years the State of Amazonas used 33 million trees, and only 3.2 million were replanted (Jansen, 1993). According to Jansen 4 million trees should be planted yearly to reach a state of equilibrium between extraction and reforestation (Jansen, 1993).

Considering results from both simulation models, it is clear, especially from the eMergy model, that there is a constant and menacing loss in forest wood stock. Forest wood transformity declines from 7.321 E6 sej/J at year one to 1.615 E4 sej/J at year 80 (Table 16). Log stock transformity maintains a relatively high level, between 6 and 7 E8 sej/J, due to the intrinsic value of timber within the eMergy economy.

Too much eMergy is flowing out of the system in terms of both money and products. The desired result is maximum eMergy use within Itacoatiara, but the opposite is happening. Keeping some money in the system would greatly reduce loss in transformity of the forest wood stock: if only one fourth of the money exiting the system (K19 = 0.8, instead of K19 = 3.2), this transformity has a value of 4.605 E6 sej/J at the 80 year mark, whereas the current situation has a transformity of 7.512 E5 sej/J - Table 19). Reducing the export of money would form an autocatalytic loop causing growth and making openings for more people (Figure 20).

Keeping the eMergy Investment Ratio from getting too high, as it is now, would make local products viable for local use. At present, the local plywood industry is too intensive and its products are too expensive for local use. Because of this, building houses now in Itacoatiara with finished plywood products would just lower assets, decreasing even further the forest wood stock transformity (down to 2.469 E5 sej/J - Table 19), assets transformity (only 9.475 E4 sej/$ - Table 19) and lowering eMergy/money ratio (6.0787 E12 sej/$ - Table 19). More money would be buying less eMergy (Figure 21).

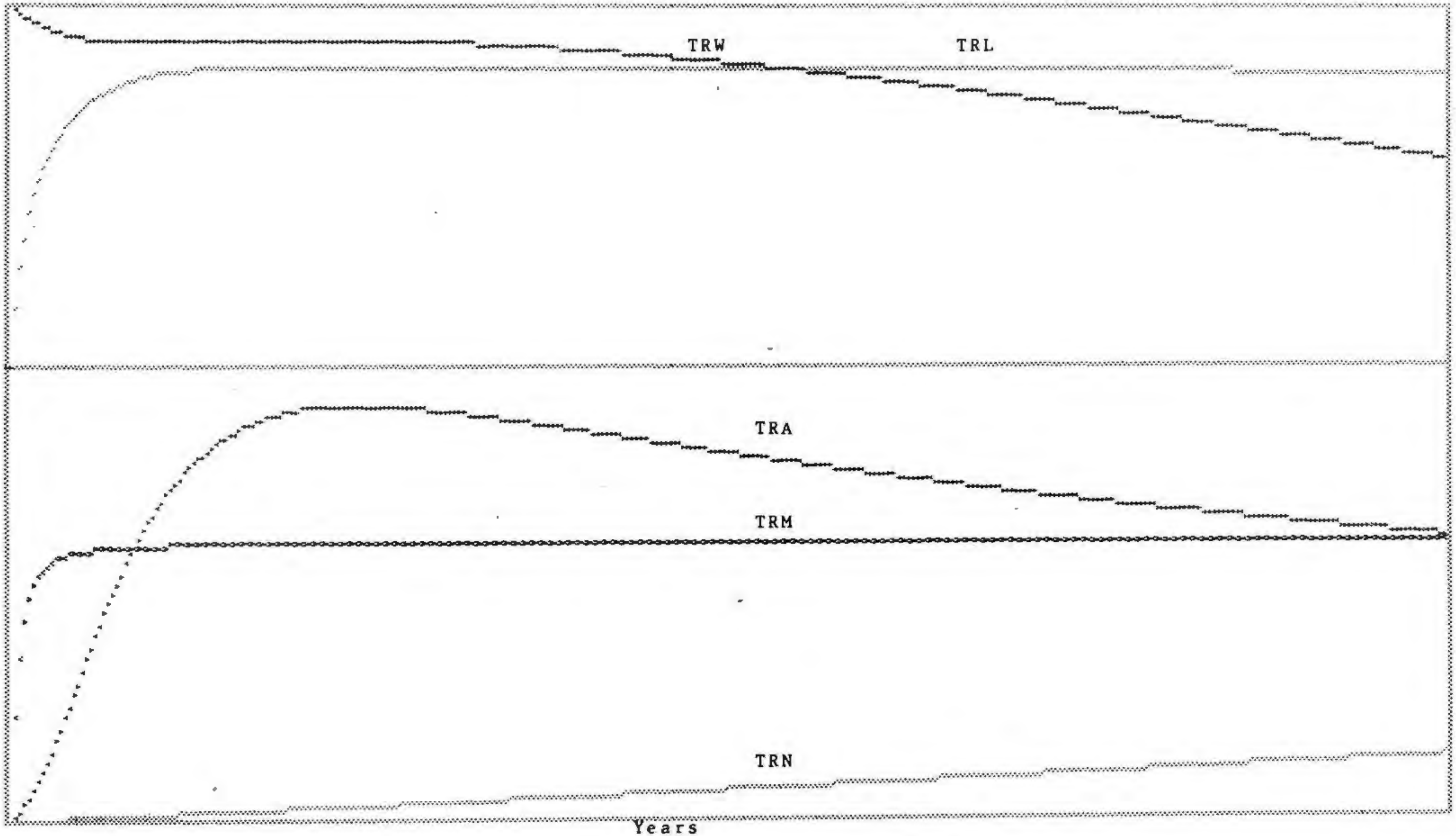


Figure 20 - eMergy simulationresults: sending just one quarter of the money from sales out of the system.

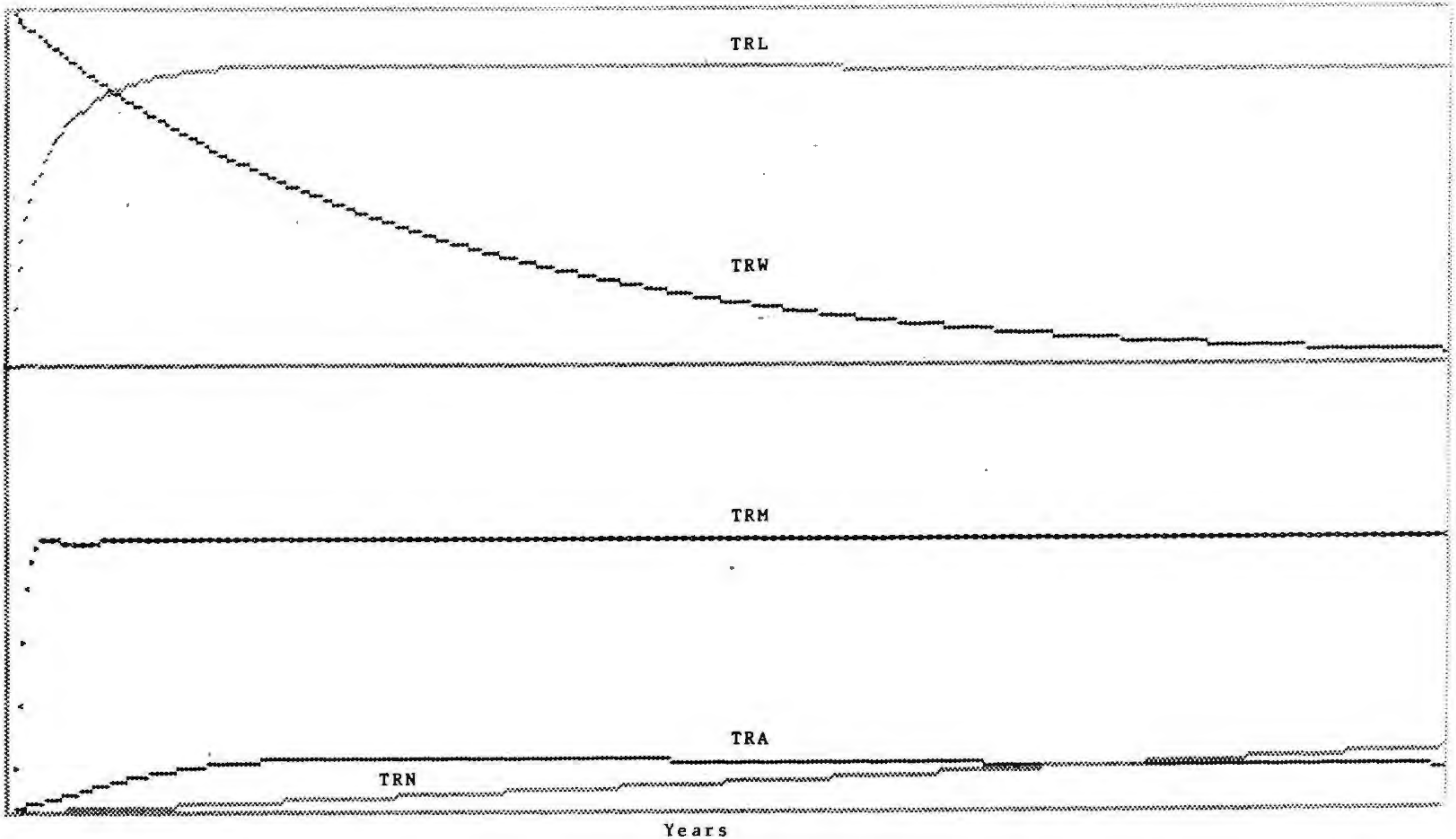


Figure21 - eMergy simulation results: sending only 1/4 of processed plywood to outside markets and using it within the town.

Table 19 - Decreasing money to South and increasing local use of plywood products

Coefficient		TRW	TRL	TRA	TRM	TRN
Money to South: K19						
original value	3.2	7.512E+05	6.553E+08	3.355E+05	6.08040E+12	1.36E+06
decreased value	0.8	4.605E+06	6.530E+08	6.232E+05	6.08014E+12	1.36E+06
Plywood to outside markets: K7						
original value	0.0148	7.512E+05	6.553E+08	3.355E+05	6.08040E+12	1.36E+06
decreased value	0.0037	2.469E+05	6.574E+08	9.475E+04	6.07872E+12	1.36E+06

Changed initial conditions

Population reduced from 60,000 to 6,000
Extractive area reduced from 25,000 to 15,000 ha

Reduced money to South:	K19 =	0.8
Reduced plywood to outside markets:	K7 =	0.0037
Reduced inflow of assets:	K20 =	0.1065

TRW	TRL	TRA	TRM	TRN
5.672E+05	9.122E+08	9.442E+05	6.07937E+12	1.36E+06

The effect of increasing the size of the area of timber extraction would lead to a depletion of the town's resources. Log transformity would increase due to greater transport costs, and assets would decrease. Money also would buy less eMergy. This, combined with the above consideration of a too high investment ratio for plywood production, makes the case for smaller extractive areas with more modest milling units and smaller towns (less assets and investments for smaller numbers of people, goods and services).

In this scenario a small town of 6,000 people (N = 6000), using a 15,000 Ha extractive area (C = 15000), sending four times less of its sales to outside economies (K19 = 0.8, money to South - Table 19), and one-half of the inflow of assets (K20 = 0.1065, inflow of assets), would register high transformities, that is, keep more emergy circulating within the system and adding to its vitality (9.8 sej/J for log stock transformity, TRL; 9.442 E5 sej/$ for assets transformity, TRA - Table 19, Figure 22).

The present model doesn't have a reinforcement component for forest wood stock production. If it did it could show how added assets could be used for stabilizing the economy with more sustainable forest management practices, and thus counterbalance the loss in forest wood stock transformity (TRW = 5.672 E5 sej/J - Table 19).

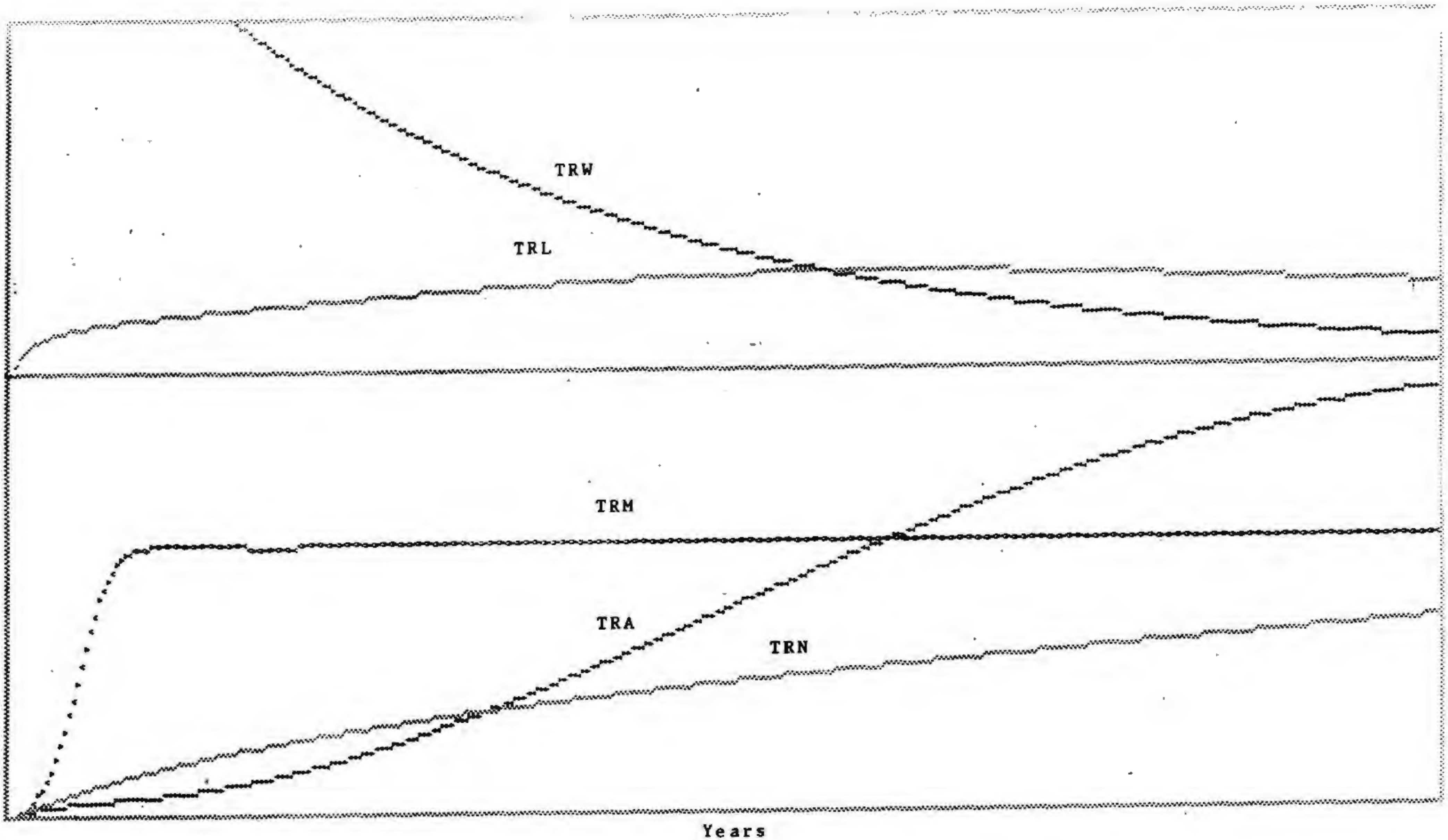


Figure 22 - eMergy simulation results: small town scenario.

The thesis that smaller units with lower eMergy Investment Ratios, using smaller timber harvesting areas and leading to scaled-down human settlements, seems to be correct from an eMergy standpoint. These systems could prove to be more stable within tropical rainforest environments than the current pattern of boom and probable future bust illustrated by Itacoatiara.

APPENDIX A - Structured interview for industry.

1. How many employees do you have at the moment?

2. Did you have more than this number working last year?

3. How many cubic meters of logs did you use over the last 12 months?

4. What are your products? What is your production per.... (dry weight, packed net weight, ready for transport/sale):

   a)
   b)
   c)

5. What are your energy costs ? QUANTITY COST/MONTH

   a) diesel oil (liters)
   b) gasoline (liters)
   c) electricity (Kwh)
   d) fuelwood or coal (m3)
   e) recycled wastes (m3)

6. What are your costs for consultants and contract work ? What is their frequency ? (monthly, annual) What are any additional costs ?

7. What is the total of your monthly pay roll ?

8. What is the total of your monthly gross income ?

9. What is your invested capital (approximately) in:

   a) machinery and equipment
   b) land assets

10. Do you have any expansion plans ? Within what time horizon ?

11. What are your limiting factors in production volumes ? (supply of raw materials, specialized manpower, workers unions, product commercialization, transport to markets, public bodies (INPS, IBAMA, etc.)

12. What are the months of greater production ? What are the months of smaller volumes of sales ?

Appendix B - Data sources

Document	Data sources	Concept	Notes
Table 2			
notes 1-7	Odum, Brown, Christianson. 1986a	95%	biological data
notes 8-19	Instituto Brasileiro de Geografia e Estatística, Anuário Estatístico do Brasil - 1989.	80%	just declared items
Table 5			
notes 1,2	várzea area - author's calculations	90%	base: RADAMBRAZIL
	albedo,sunlight,rain chem.pot.: Odum, Brown, Christianson, 1986a.	95%	possible climatic changes
note 3	Salati & Vose, 1984; Marques,Fattori,Fish, Januario, 1986/87.	98%	data agree
note 4	biomass production, Higuchi personal communication	90%	várzea is little studied
Table 6			
note 1	river's kinetic contrib.: Odum,Diamond,Brown, 1987.	90%	rivers w/ different charact.
note 2	logs volume, Bruce, pers.comm.	98%	
note 3	prices of different transport steps, Bruce, personal communication	100%	
note 4	logs volume, Bruce, personal communication	98%	
Table 7			
note 1	logs volume, Bruce, personal communication	98%	
notes 2-6	author's calculations	70-80%	medium bldg.constructn.
note 7	logs prices, Bruce, personal communication	100%	
note 8	boilers firewood, Bruce, personal comm.	100%	
note 9	used eletricity, CEAM, Companhia Energética do Amazonas	100%	payment registers
note 10	used fuels, PETROBRAS, Manaus	100%	sole supplier, registers
notes 11-13	interviews, sindicates, businessmen	90%	
note 14	goods invested/year, Bruce, pers.comm.	95%	
Table 8			
note 1	Odum, Brown, Christianson, 1986a	95%	
note 2-11	Munic.Office,IBGE -Manaus,ICOTI.	80%	precarious data
note 12	fuels, PETROBRAS	90%	some buy in Manaus
note 13	eletricity, CEAM	100%	payment registers
note 14	goods consumed, ICOTI, SEFAZ - listing of declared sales of 100 major commercial houses. Additional calculations by author	80%	
notes 15-16	Munic.Office, ICOTI, SEFAZ, author	80%	
Figure 15	popul.growth/urbaniz.rate,IBGE Manaus.	95%	
Table 10			
eMergy	National eMergy/capita: author	70%	many variables
	eMergy needs/capita	70%	many variables
extrativ.	extrative manpower: Bruce & author	70%	
	volume extracted by each family unit Bruce & author	70%	
	used fuels: Bruce & author	70%	
	prices in the different steps of extraction Bruce, personal communication	100%	

\ppendix B - Continued

)ocument	Data sources	Concept	Notes
nodels			
W	forest wood stock below/above ground Fearnside, personal communication	90%	várzea is little studied
:oef. J1	net biomass growth, Odum, pers. comm.	90%	várzea is little studied
:oef. J2	annual biomass loss, Odum, pers. comm.	90%	várzea is little studied
:oef. J3	volumes logs cut, Bruce, pers. comm.	90%	
:oef. J4	annual log stock, Bruce, pers. comm.	95%	
:oef. J5	annual loss of logs, interviews and author	85%	
:oef. J6	logs used/year, author	90%	
L	annual logs stock, averages, Bruce, personal communication	95%	
A	Town's assets, IBGE,Munic.Office, others	80%	
:oef. J9	goods to population, ICOTI, 1982	80%	
:oef. J15	goods to extractive activities, Bruce, personal communication	90%	
:oef. J20	influx of goods and services, SEFAZ, listing of the 100 major commercial enterprises	80%	only declared busines
M	industrial capital stock, Bruce, *personal communication*	90%	
:oef. J7	flux of finished product and money return, various sources (interviews)	90%	
:oef. J14	goods and services , author's estimates	70%	
:oef. 19	money sent to the South of Brazil, various sources (interviews)	90%	
N	population, IBGE-Manaus	95%	
:oef. J10	population growth rate, IBGE-Manaus	95%	
:oef. J11	mortality rate, IBGE-Manaus	95%	
:oef. J12	migration rate, author's estimate	70%	no official data
:oef. J13	immigration rate, author's estimate	70%	no official data

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