EMERGY SYNTHESIS 6:
Theory and Applications of the Emergy Methodology

Proceedings from the Sixth Biennial Emergy Conference,
January 14 – 16, 2010, Gainesville, Florida

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December 2011

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New Emergy Indices for a Prosperous Way Down

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ABSTRACT

Most of emergy indices, as defined up to now, are well fitted to reinforce the human strategy of using non renewable resources for free and without any concerns with social and environmental impacts. As the world becomes aware that the biosphere resilience limits are being over-passing, new approaches for ecological-economical systems interpretation are necessary to move from the continuous growth of Capitalism to a different social system that can be based on the sustainable use of natural resources and social justice. The solution requires leaving away the idea of maximizing emergy use as unique criteria for public policy and the adoption of Conscious Decline Perspective for a transition to Sustainable Societies, all over the world. From now on, emergy indices should consider natural productivity, environmental services, negative externalities, and the environmental loading inherent to different life-styles. Humanity should adopt new concepts as fitness between biological capacity and consumption at different scales, ecosystems recovery, decentralization of production and consumption with new life styles and high levels of recycling (Eco-Units configuring Eco-Regions). It is necessary a global social process aimed to balance and overcome the forces involved in the social-environmental phenomena. In that sense, communication strategies for rapid Systems Education are needed to make it possible a transition to a civilization based on ecological rural systems supporting small cities.

INTRODUCTION

Since 1712, when fossil fuels were used by first time to amplify human work, the human economy grows continuously converting natural stocks in to human assets (including population) in a self-reinforcing process. The industrial economic system powered by capitalism ideology is moving rapidly to a general collapse. Economy growth is driven by search of profit not recognizing physical, ethical or ecological limits. All over the planet, sustainable systems are transformed into oil dependent systems. Productivity increases as well as the population that still thinks that progress without limits is possible. Scientists (Odum & Odum, 2001; Georgescou-Roegen, 1971; Diamond, 2006; Larouche, 2009 and others) point out that after a prolonged period of growth there will be a stop and then a big decrease that can happen as a tragedy or as a organized process; it is up to us to decide how the Degrowth could be.

Odum and Odum help us to understand the decay process and offer a guide for a peaceful pathway with priorities and strategies. Considering that it will be necessary the use of emergy diagnosis methodology to face up the transition to more renewable systems, it is indispensable to discuss if the methodology indices are fitted for this new time (Ortega, 2002, 2005, 2009). The objectives of this work are: to discuss the challenges to promote a Prosperous Way Down (PWD), to observe agriculture trends in last centuries in order to have ideas about how to change the production and consumption systems to increase their renewability and, finally, to discuss the emergy indices trends in the past and future of human ecosystems.

CONCEPTS AND THEORIES USED IN THIS WORK

Prosperous Way Down

In theory, PWD is the ecological and social interaction system between the human beings and the environment that could be maintained without the use of non renewable stocks and flows. Because capitalism is based on "continuous growth" and "unconscious consumption" and dont have ethical values it cannot be its framework. It is not an industrial-minded anti-ecological and uncritical socialism. A Prosperous Way Down implies in: new social concerns and commitments with nature (Biosphere and Ecosystems). Probably it has more affinities with eco-socialism and a pacific anarchism. In order to become more popular the Prosperous Way Down should make an effort to explain how it help to solve the main challenges that humanity is facing: (a) measuring the world's renewable support capacity and comparing it with the increased support capacity obtained by using non-renewables; (b) forecasting population reduction during decline considering degraded ecosystems; (c) understanding the human interaction with biosphere throughout history; (e) proposing correct solutions in a global risk situation, and; (f) formulation of new models for ecological production-consumption systems.

The analysis of a project for using an area should consider how the available resources in the area are linked to long term processes realized in the past (geological, biological and sociological processes) and how to design the system with functional areas to take care of biophysical and social restraints.

Recovering Sustainability of Agriculture

Food production can be based on local renewable resources and local markets or on external non-renewable inputs and external markets.

Sustainable rural production depends on: (a) solar energy (sun, wind, rain); (b) water basin resources and environmental services (water, humus, sediments, regional biodiversity); (c) soil minerals mobilized by local soil biota; (d) nitrogen fixed by bacteria; (e) environmental services derived from the maintenance of local biodiversity and (f) animal and human work, infra-structure, organization and ecological culture.

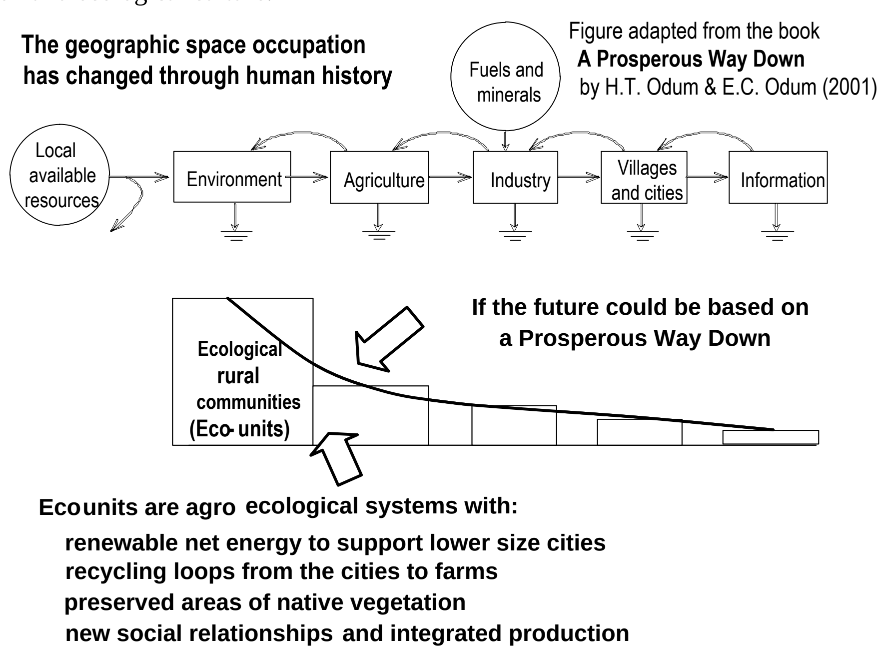

Figure 1. *Future interaction with biosphere.*

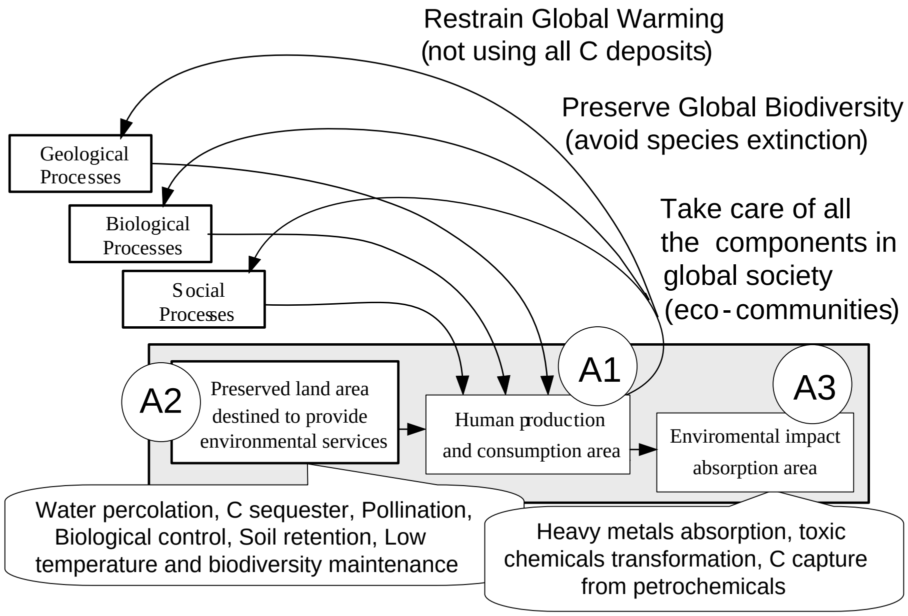

Figure 2. *Understanding global risks in order for making proposals.*

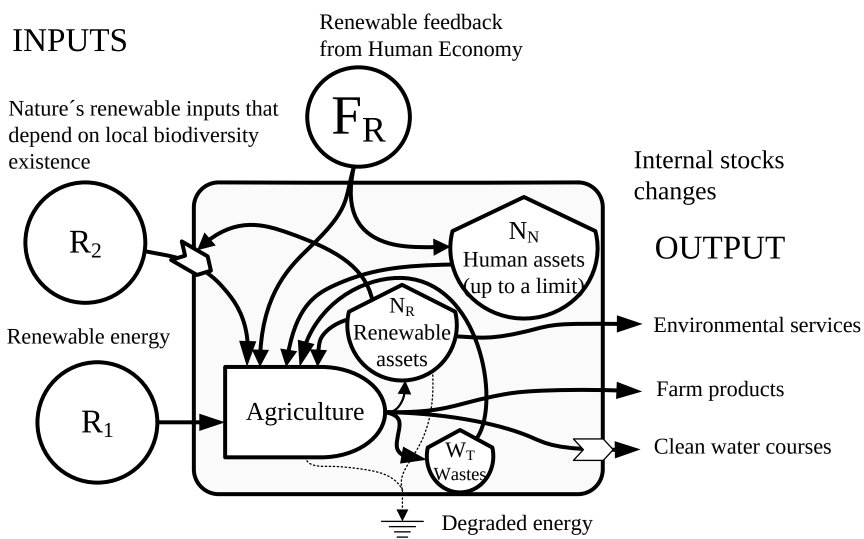

Figure 3. *A sustainable agriculture depends on renewable flows supported by ecological internal stocks (soil, biodiversity) and renewable flows from external renewable economy.*

Agriculture became a non-renewable system due to: (a) deforestation (clear cutting) and social exclusion; (b) use of fertilizers, pesticides, herbicides and intensive mechanization; (c) establishment of costly infra-structure; (d) use of electricity, fuels; (e) use of chemical products (lime, plastics); (f) use of seeds produced out of the region; (g) use of subsidized animal feed, and (h) discharge of animal waste to rivers.

Ecological corn production based on local renewables varies from 500 to 5000 kg/ha/year, in parallel with the production of a great diversity of plants and animals. The agrochemical productivity for corn varies from 2000 to 12000 kg/ha/year. It represents an increase of 2 to 3 times compared to ecological method, but on the other hand, these plantations destroy native vegetation, biodiversity and

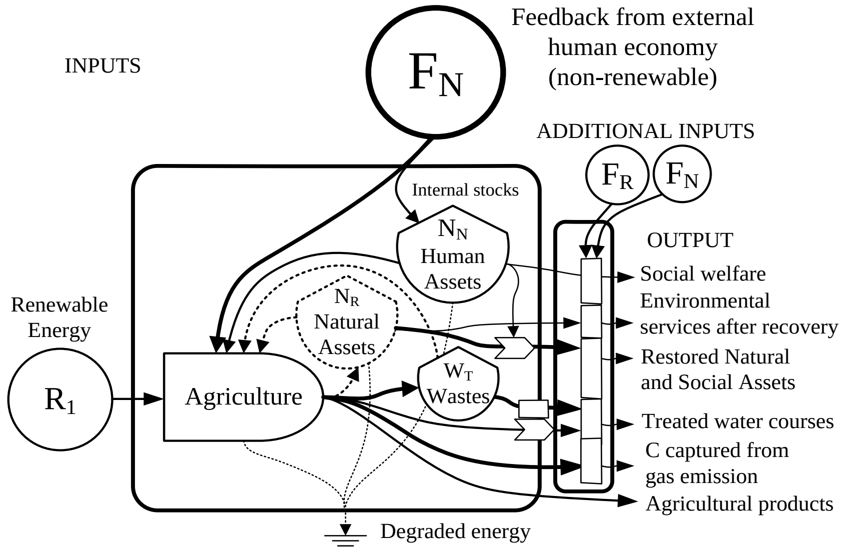

Figure 4. *A non sustainable agriculture depends on the destruction of internal ecological stocks and its substitution by external non renewable inflows. Usually neither the costs related with the loss of environmental services nor the costs related with the care necessary to care with negative externalities are not included. The inclusion of these "additional inputs" increase the price of products.*

ecosystem functions; pollute; throw away from the country side a lot of small farmers and rural workers, concentrate income and depend on massive use of imported chemicals. Agro-chemical farms have a high environmental and social impact, and very low sustainability. They have high profit because their negative externalities are not charged! This is an important fact that makes difference in public policy.

METHODOLOGY

Modeling

The diverse alternatives of production of food, fiber, fuels, environmental services and negative externalities can be diagramed in order to preview the future trends in rural production and urban consumption. Figure 5 shows the diagram of a rural system for a more complete accounting. The aggregated flows diagram should include the care with negative externalities as well as the environmental services production.

Meaning of terms used in Figure 5 are: R: Renewable (energy and materials); N: Internal stocks (as soil and biodiversity) that should be preserved; M: Materials from external economy that can be considered as renewable (M_R) and nonrenewable (M_N); S: Services from external economy that can considered as renewable (S_R) and nonrenewable (S_N); E: output (main products, environmental services, system losses).

A PWD farm has an up-stream area (A2) devoted to provide infiltrated water, soil, climate regulation and wood, an area for production (A1), and an down-stream area (A3) to absorb the environmental impact due to the use of inputs derived from nonrenewable resources. This area is composed marginal areas as wetlands, high declivity lands, and riparian vegetation that can mitigate diverse impacts. This area is called as "treatments and special care of residues." If the effluents are treated they are called "low impact flows" but there is the possibility of "high impact flows" if the wastes are not treated within the farm. Besides the economy inputs used in production, additional inputs are needed for residues treatments to transform high impact flows to low impact flows (some of these could have economic value).

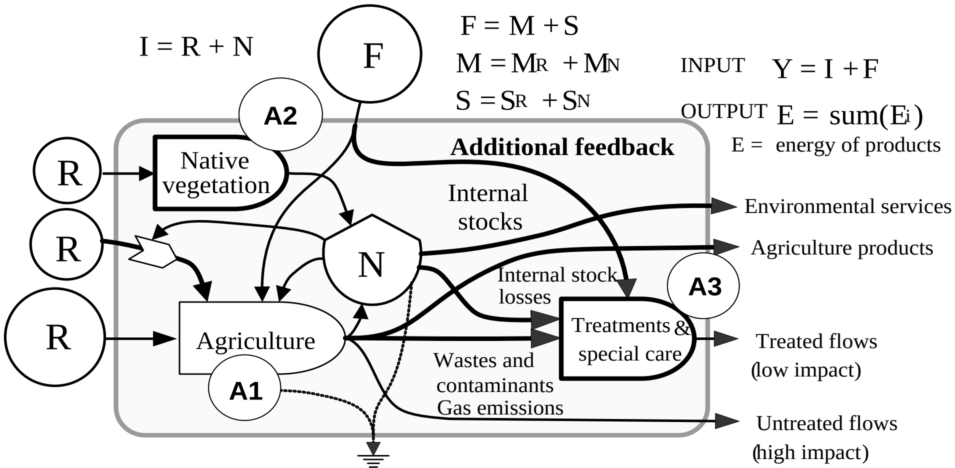

Figure 5. *Diagram of a rural system for a more complete accounting showing three functional areas for crop production (A1), services production (A2), and impact absorption area(A3).*

Simulation Procedure

When the farms incorporate non renewable energy, materials and information, there are changes as those showed in Figures 6 and 7.

The timeline from left to right shows the change of inputs used in agriculture during the last 130 years, after the introduction of chemicals, fuel and irrigation based on nonrenewable energy. In emergy terms the materials show to be the greatest input but services required for negative externalities are increasing (Ortega et al. 2009).

Description of flows considered in Figure 6a: solar energy flows, mainly rain, are a constant flow (R1), renewable materials obtained by micro-biota from air and soil minerals decrease as biodiversity is lost (R2), renewable flows (water, sediments, organic materials) from water basin are almost constant (R3). Materials increase (M). Services can be divided in conventional services (S) and additional services needed to solve the problem of externalities (X). Climate change externalities remain even if the public policy changes to promote PWD.

Product prices are decreasing while input prices are increasing, the profit per area is getting lower, therefore small farmers cannot keep working and big farmers buy their lands. As result, the income become depend no more on productivity but on land size (“income concentration”). Scientific reports inform that transformation of land covering is producing climatic change.

RESULTS AND DISCUSSION

Figure 8 shows the change of emergy aggregated flows as well as the change of emergy indices during Growth and Decline.

The Proper Public Policy

The renewable inflows decrease produced a decrease of renewability. The use of nonrenewable inputs replaced renewable stocks and flows and causes the loss of natural fertility and resilience of the farming system, the production at first increases but as the biological structure is lost the system cannot respond positively to the use of more chemicals.

In the future instead of growth of nonrenewable urban economy there will be necessary to support and promote ecological ruralization (Günther, 2004).

In terms of public policy it will be necessary to measure environmental services (water percolation, carbon capture, genetic vigor maintenance, biologic control, ecological culture) to be paid and negative externalities (pollution, soil erosion, cost of urban services for marginalized population, etc.) to be charged to farmers. Another important public policy concerns with the transferring of urban populations that nowadays are concentrated in congested cities to the rural areas that are degraded by extensive monocultures.

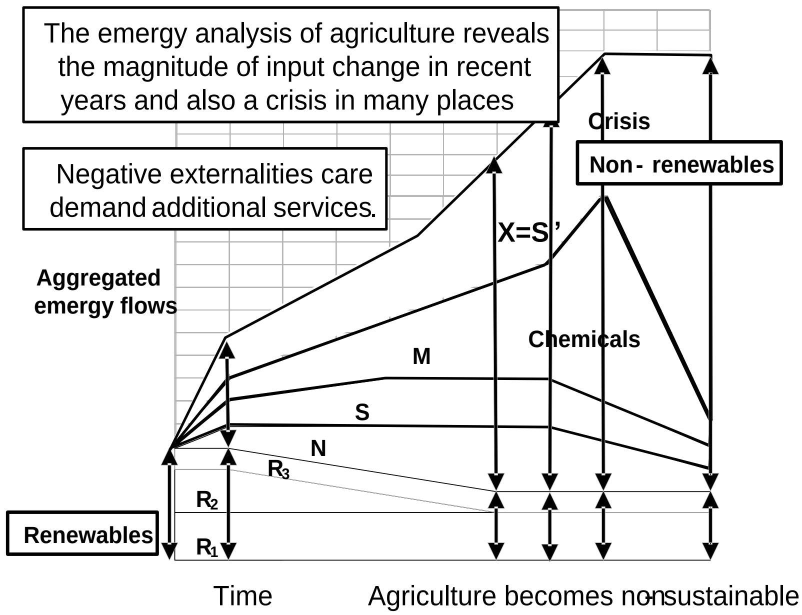

Figure 6. *Changes in emergy flows during the last two centuries.*

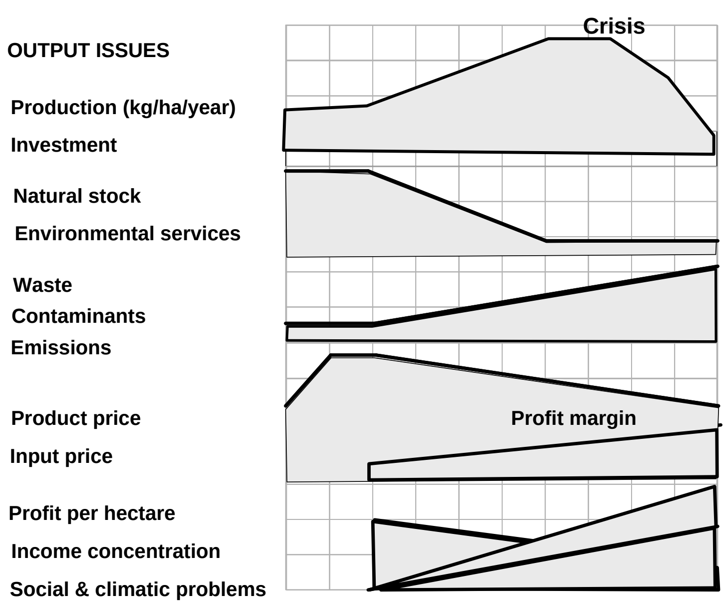

Figure 7. *Change in farming along last two centuries op productivity, (b) the natural stocks are destroyed and the environmental services they produce are reduced.*

The Emergy Indices

The emergy methodology is able to measure the value of all the inputs of a system in terms of the work previously realized by nature and human beings to produce each input. As all the inputs can be expressed in the same terms (incorporated work), then all the inflows can be compared, individually or as aggregated flows (R, N, M, S). Total inflow from nature (I) is the sum of renewable inflows (R) and

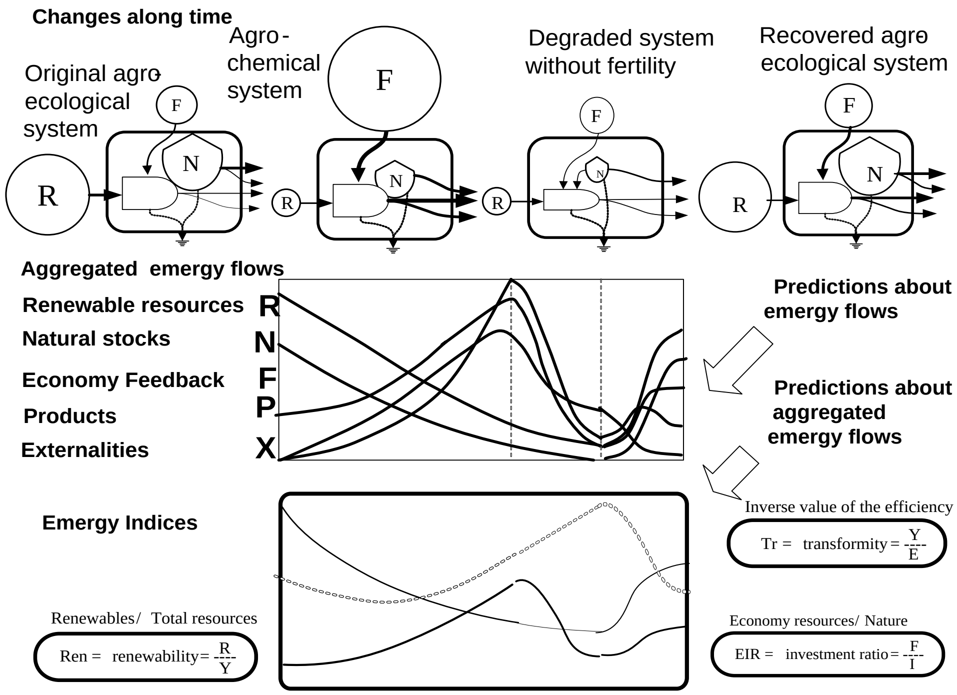

Figure 8. *Trends in world agriculture and recovering through ecological and social public policy.*

nonrenewable inflows (N). Feedback from Economy (F) is obtained adding the work contained in materials (M) and services (S). In ecological economies a fraction of materials and services can be renewable, therefore: $M = M_R+M_N$ and $S = S_R+S_N$. The output is denominated yield (Y) and when expressed in emergy terms it incorporates all the inflows: Y = I+F. When aggregated emergy flows are compared very interesting indices were created (Tr, EYR, Ren, ELR, EER, EIR) that allow measuring the thermodynamic behavior of any system.

Considerations for Emergy Indices to be Used in PWD Systems Diagnosis

Usually R considers the greater renewable flow from direct solar radiation, wind, rain, geologic up-lift and tides. The suggestion is to consider other important renewable flows as: nutrients incorporated by biota (microorganisms and trees) from air and soil; water, sediments and organic matter from rivers and aquifers that come from the water basin, and finally gases from air that became important due to climate change.

Renewables = direct flows + biodiversity dependent flows + regional flows

$$R = R_1 + R_2 + R_3$$

Feedback should include the materials and services needed to solve the externalities.

$$F = M + S + X$$

Each M and S flow has a renewable fraction: $M = M_R + M_N$ and $S = S_R + S_N$
Therefore, F and Y have a renewable fraction: $F = F_R + F_N$ and $Y = Y_R + Y_N$
The transformity (Tr) also has a renewable fraction.

$$Tr = \frac{Y}{E_p} = \frac{Y_R}{E_p} + \frac{Y_N}{E_p} = T_R + T_N$$

In EYR, its terms have opposed effects, and then this indicator must be divided:

$$EYR = \frac{Y}{F} = \frac{F + R + N}{F} = 1 + \boxed{\frac{R}{F}} + \boxed{\frac{N}{F}}$$

$$\boxed{RS = \frac{R}{F}}$$ **Renewable Support**

$$\boxed{NS = \frac{N}{F}}$$ **Non Renewable Support**

$$\boxed{EYR = 1 + RS + NS}$$

Renewability should consider all renewables including M_R and S_R

$$\mathrm{Ren} = \frac{\mathrm{R}}{\mathrm{Y}} = \frac{\sum \mathrm{R_i} + \mathrm{M_R} + \mathrm{S_R}}{\mathrm{Y}}$$

ELR should consider F_R and F_N:

$$\mathrm{ELR} = \frac{\text{renewables}}{\text{non renewables}} = \frac{\sum \mathrm{R_i} + \mathrm{F_R}}{\mathrm{N} + \mathrm{F_N}}$$

EER should include: environmental services and subsidies

$$EER = \frac{\text{Y produced}}{\text{Y received}} = \frac{\text{products} + \text{env.services}}{\text{sales} + \text{subsidies}}$$

$$EIR = \frac{F}{I} = \frac{M + S}{R + N}$$ ⇒ A new definition of EIR is possible: without N support $$EIR = \frac{F}{R} = \frac{M + S}{R}$$

Recycling is very important in Agroecology there must be and indicator for this

$$\mathrm{WR} = \frac{\mathrm{C}}{\mathrm{Y}} = \frac{\text{internal recycle flows}}{\mathrm{Y}}$$

The End of Oil, the Loss of Environmental Stocks and Flows and Climate Change

R/N shows to be a good indicator of benefit/cost ratio in recent studies. New emergy indices are needed to consider climate change, resilience and social metabolism.

Eco-unit a proposal for a PWD

The eco-unit concept corresponds to a cluster the PWD farms previously described that could use also the Permaculture concepts for regional and local planning (Figure 11). The idea is to be the basic economic unit for an ecological production system that can optimize the internal flows by means of integration of people and activities such as farming, cattle husbandry, agro-forestry, products processing and local basic services supplying. It should be designed to contribute with net renewavle emergy to local and regional development, by means of ecological design using emergy indices as framework and social attitudes to make possible its participation of regional networks and to provide ecosystems recovering and carbon and metals sequestering in order to contribute to global warming mitigation and to avoid a catastrophic collapse.

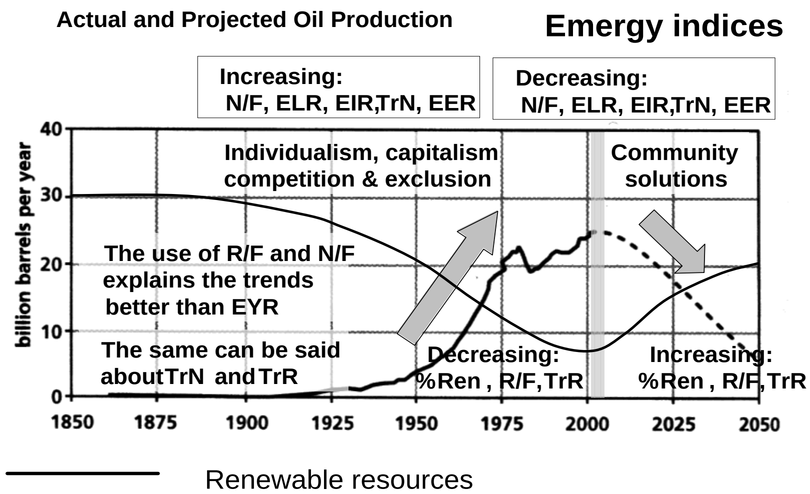

Figure 9. *Emergy indices variation during growth and degrowth (PWD).*

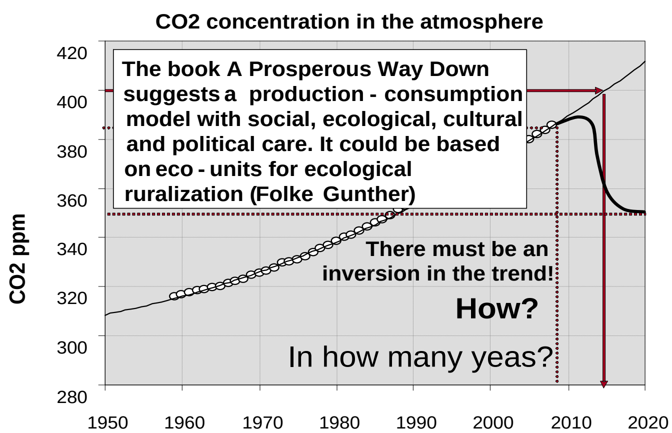

Figure 10. *Global warming is a problem that was not detected in previous emergy studies, but its solution is quite related to alternatives proposed in a Prosperous Way Down.*

CONCLUSIONS

a) For a PWD it will be necessary to adopt high renewability production & consumption systems; therefore, it is convenient to study the prototypes that exist around the world. These studies should include administrative, political, and psychological frameworks.
b) The study should use more complete energy flow diagrams and the proper emergy indices.
c) Its diagnosis should promote an open and broad discussion about the transition to sustainable societies all over the world, promoted by social movements, academy and governing authorities.
d) Empower the people: do not omit good information. It is necessary to measure and include all negative externalities, the resilience threats and environmental services.

ACKNOWEDGEMENTS

The author is grateful to Mileine Zanghetin for her help in diagrams drawing and also to the students and research collaborators for the exchange of ideas during research.

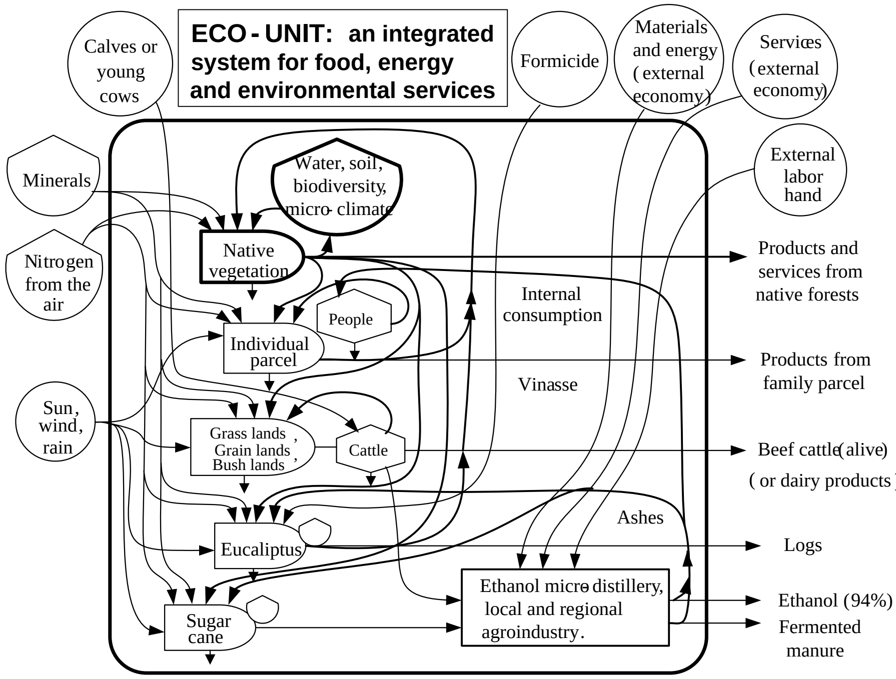

Figure 11. *An eco-unit is a rural farm that is adapted for PWD: it has the three different areas needed to provide social, ecological and climate recovery (Ortega et al., 2008).*

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