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A PROSPEROUS WAY DOWN

Elisabeth C. Odum - Professor Emeritus
Santa Fe Community College, Gainesville, Florida

ABSTRACT
The first premise of the Prosperous Way Down is that fossil fuels are being used faster than the earth is making them and that there are (and will be) no new energy sources with as much power as fossil fuels. The second idea is that human civilization can be prosperous as it goes down to a lower energy world. To explain these hypotheses there is a review of the principles of emergy, its calculation and its use in evaluations and predictions. Tables of emergy per person and emergy per dollar of many countries are the bases for evaluations of international relationships. Examples are given of the use of emergy in possible solutions of problems like unequal migration, production, war, terrorism, and international trade. Scientists can use these methods to show how civilization can decline thoughtfully rather than collapse miserably.

1. INTRODUCTION

This paper is based on one of H. T. Odum's special projects: the future of human civilization. He put together facts, explanations and predictions in many papers and the book we wrote together, A Prosperous Way Down (Odum and Odum, 2001). Instead of anticipating a crash, a possible, hopeful, view of the future is predicted. These discussions and conclusions are based on two hypotheses. The first, with which most scientists agree, is that we (the world and our economy) are going down (there will be fewer resources to live on). The second, less considered, is that the lower energy future can be prosperous and happy – depending on our human actions. Our plans and activities must include the world environment as well as the economy, as shown in Figure 1.

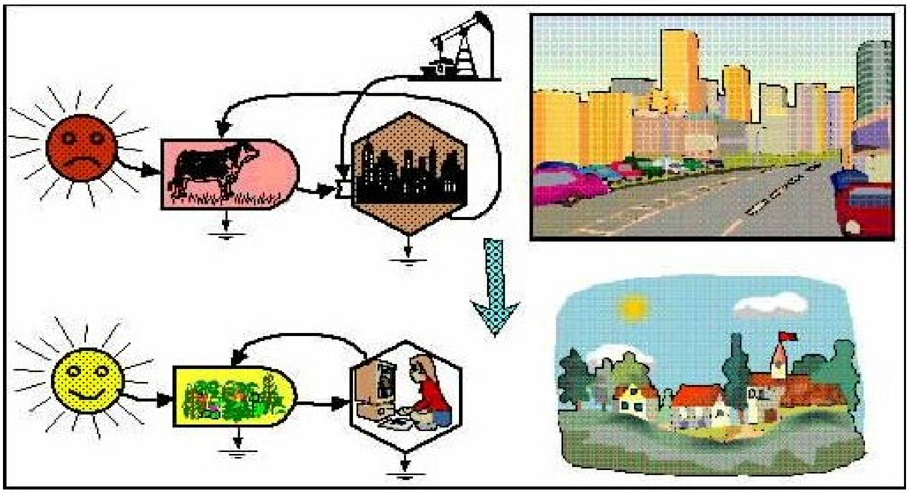

Figure 1. This picture of the trend illustrates the hypothesis with two parts: we are going to live with fewer resources and we can be prosperous and happy with fewer resources.

2. ENERGY RESOURCES

Our economy is based on fuels and we are using them up faster than the earth is making them. Figure 2 shows the Campbell summary graph of oil production - from the Gas and Oil Industry report (Campbell, 1997).

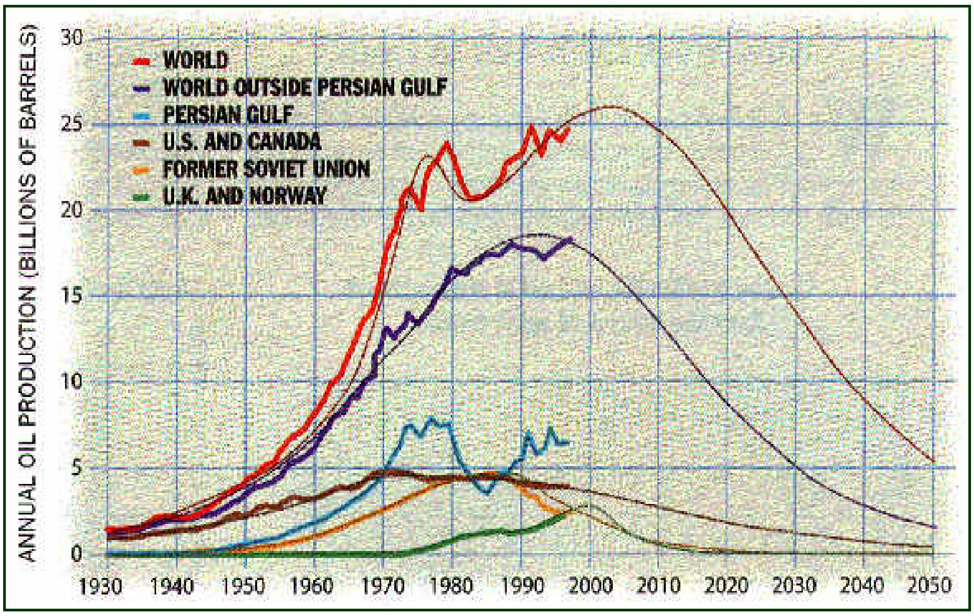

Figure 2. This graph from a Gas and Oil Industry report shows world oil production peaking in about 2004.

Another interesting graph from a later Campbell paper (Campbell, 2002) calculates our use of already-discovered fuels, contrasted to our projected demand.

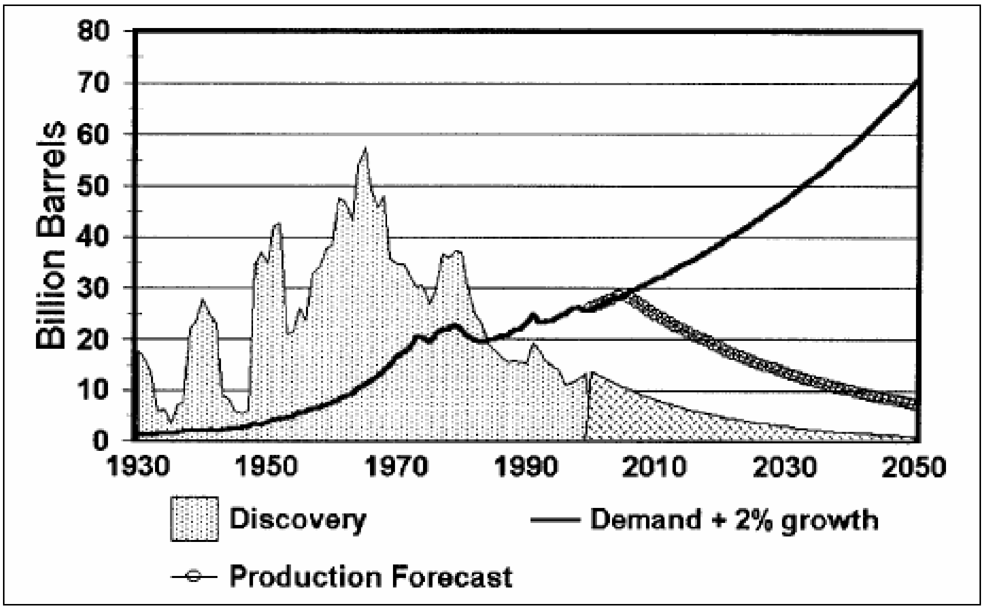

Figure 3. Discovery trend. Oil discovery peaked in the 1960's, when we were finding more than we used. Now, the situation is reversed, meaning that the historic trend of growth of about 2% a year cannot be maintained as we consume our inheritance from past discovery.

An important part of the scenario is that there are no new energy sources with as much power as fossil fuels. Table 1 is a short summary of the proposed alternative energy sources and their possible uses. None of them can take the place of fossil fuels.

Table 1. Review of alternate energy sources.

Nuclear fusion	It is the process of burning hydrogen, as on the sun. It would be like having the sun on earth, too hot to be cooled enough for humans to use it.
Nuclear fission	The supply of U235 may run out before fossil fuels, although its use can be extended by breeder plants. One of its problems is that Plutonium, a byproduct, can be used for making bombs and is very lethal. Another unsolved problem is the disposal of radioactive wastes.
Solar voltaic cells	Experiments show that the photovoltaics use more energy in materials than the electricity they produce.
Wind	Wind is a net source in areas with strong steady winds. The more equipment and computing needed, the less net electricity is produced.
Biomass	This cannot be used extensively to produce electricity since it will be needed for food, shelter, and clothing.
Hydro-electricity	In mountainous areas hydroelectricity is a net source, but almost all the rivers have already been dammed.
Hydrogen	Hydrogen to use in fuel cells is proposed. But since it takes more fuel to make the electricity needed to break up the water or methane into hydrogen than the hydrogen produces, it is not a net energy or economic source.

Human civilization lives on two kinds of energy sources: renewable, like sun, wind, rain, tides, and nonrenewable, like fossil fuels, uranium, copper. The computer model in Figure 4 shows the use of these sources. When this program is run, it produces the graph in Figure 5.

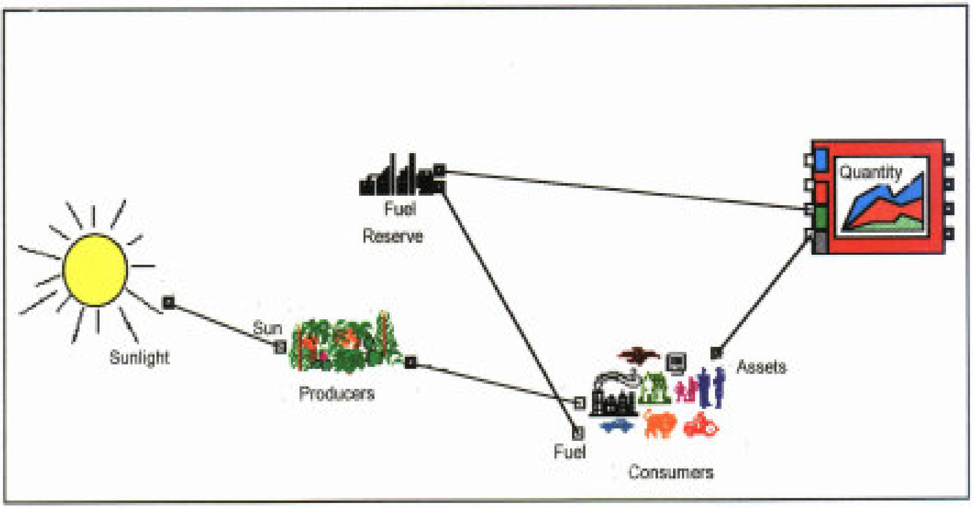

Figure 4. A computer model of the economy showing economic consumers using the two kinds of energy sources: renewables (sunlight) and nonrenewables (fuel).

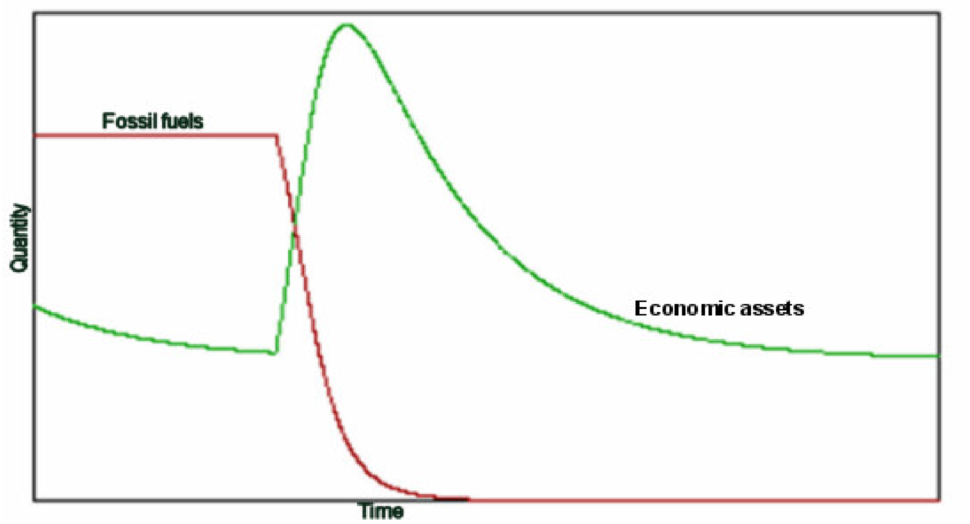

Figure 5. Before fossil fuels were used, the economy was supported by the renewable sources. When fossil fuels began to be used, economic assets grew rapidly. As fuels are used up, economic assets will again be supported by the renewable energy sources.

Two questions are asked. Where are we on this graph? Using predictions in Figure 1, we are near the top or just to its right. A harder question is how we can make the coming down slow and smooth and prosperous, or will we crash by ignoring predictions and continuing the fast life of super jets, oversized cars and vans. We believe people's behavior can be changed by learning new ideas; that is why we wrote this book. (Odum and Odum 1999).

To understand where we are at present, we need to consider the proportion of renewable to nonrenewable resources. The world is running on 60% nonrenewables, the U.S. 75% and Brazil 62%. Renewables will be maintained, but we will have to start using less nonrenewables. To keep the same standard of living, since nonrenewables are being used up, we either reduce the use of nonrenewables or reduce the population, probably a combination.

3. EMERGY PRINCIPLES FOR EVALUATIONS AND CALCULATIONS

To measure these quantities such as various energies and materials, for comparison and to make choices, we have the special concept, emergy. Different energies and materials can be measured on the same scale using emergy calculations. The following is a basic explanation of emergy principles.

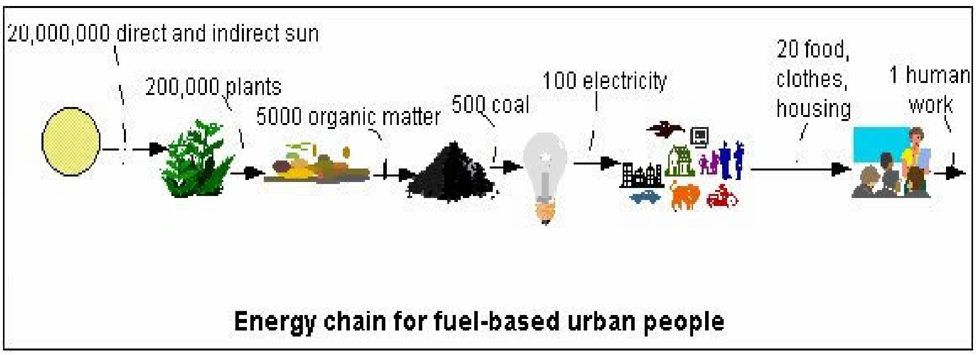

Figure 6. 20 million joules of direct and indirect sunlight are used to produce each part of this energy chain. 20 million joules is the solar emergy of each component.

This human energy food chain shows the joules in the units as they are processed from sun to electricity to human work. At each process some energy is used up, lost from the chain. The emergy of each unit is the amount of energy it took to make it: all of them used the whole 20 million joules of sunlight. For example, think of you, a human. If I put you in an oven, how much heat would I get out of you? That's your energy. But to evaluate the emergy of a human you count all the different kinds of energy taken to make him, from genetics, to tender loving care, to school, trips, everything that has gone in to make him. Your emergy is a much bigger quantity than your energy. Transformity is a related special concept. Transformity is the amount of solar emergy joules it takes to make 1 joule of a material or service. The abbreviation for solar emergy joules is sej. Table 2 compares energy, emergy and transformity for quantities in the diagram in Figure 6.

Table 2.Comparison of energy, emergy and transformity for quantities in Figure 6.

	Sun	**Electricity**	**Food, housing**
Energy	20 E6 joules	100 joules	20 joules
Emergy	20 E6 sej	20 E6 sej	20 E6 sej
Transformity	20 E6 sej/20 E6 J = 1sej/J	20 E6 sej/100 J = 20 E4 sej/J	20 E6 sej/20 J = 1 E6 sej/J

This is a hierarchical concept of value. Power and quality are different from physical quantity. This is a way to quantify the idea everyone has that the value of something is more than just the energy and materials in it. This does not represent the monetary value. Price is not its emergy value; price is just what someone would pay for it. Using emergy as the way of comparing different things on the same scale, its emergy value, we can calculate different choices.

4. CALCULATIONS OF EMERGY

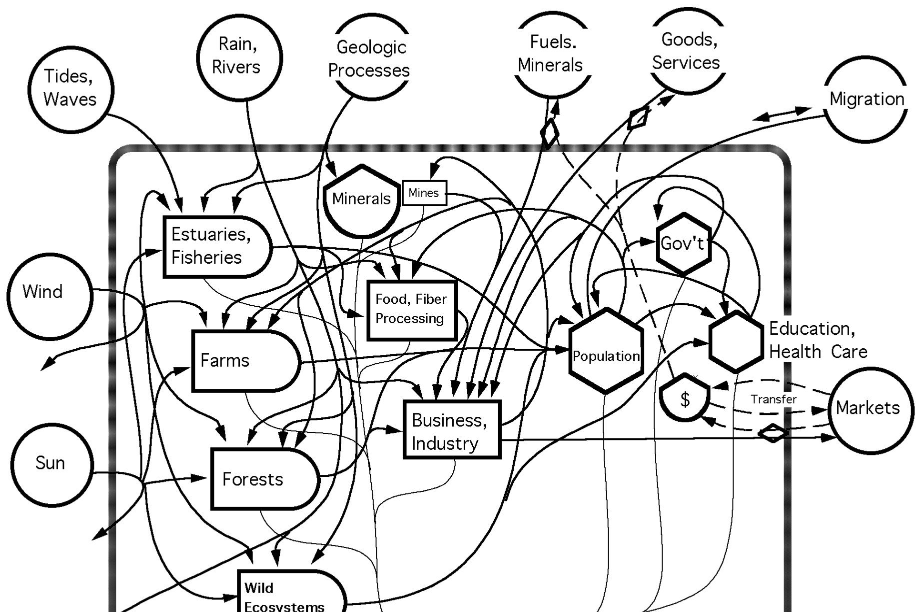

Figure 7. National emergy values are based on calculations of flows and storages in the systems diagram.

Various problems the world is facing can be evaluated using emergy calculations. The purpose here is to use these calculations to make decisions as to how to keep the economy and environment prosperous as resources become more limited. Several international questions are studied. To answer basic questions about countries, the emergy use per year for each country is needed. The national diagram in Figure 7 is a general template used to start the research. To obtain the total emergy used in a country in a year there would be other particular items to be calculated.

5. IMMIGRATION AND EMIGRATION PROBLEMS

Over the world there is the problem of migration of people. They move for many reasons but the primary one is to find a better life, a higher standard of living. Since emergy includes all uses, it is a more accurate measure of standard of living than dollars. To calculate the emergy use per person per year, divide the total emergy use by the population. Table 4 shows the emergy use per person for the countries in Table 3. When all the flows and storages are calculated in original units, then multiplied by the sej/unit, the result is emergy in sej. The emergy use is dependent on renewable sources (size of country, sun and rain) and the nonrenewable sources (fuels and minerals) and imports. Recent calculations of emergy per country per year are summarized in Table 3. These quantities are very different from the countries' economic production since they include the natural resources.

Table 3. Comparisons of Yearly Emergy Use of Nations.

Nation	**E22 sej/year**
USA	1150.0
China	917.0
Russia	703.0
India	522.0
Japan	360.0
United Kingdom	287.0
Brazil	277.0
Canada	268.0
Germany	153.0
France	144.0
Australia	138.0
Italy	126,5
Indonesia	125.0
Mexico	61,4
Saudi Arabia	55.8
Argentina	45.2
Chile	28.0
Austria	25.8
Switzerland	24.5
Denmark	17.8
Portugal	17.6
Paraguay	4.8

You can predict migration pressures by comparing the emergy per person for the different countries. For example, there is more migration from Brazil to the US, and from the U.S. to Australia and Canada than the other way. Emergy/person depends both on the emergy and the population. To lessen pressure for immigration and emigration we need more equity of emergy/person across the world.

If we could equalize emergy/person that would that lessen the likelihood of war too. Isn't terrorism one way groups of people with low emergy/person feel they can affect the distribution of resources? Here's a local example: in your city unequal emergy/person encourages crime against property. The response is often a gated community to keep out people who want your resources. Looking at the table there are two possibilities for reducing inequality between countries. Increase the emergy use by increasing production and reduce the population.

6. GLOBALIZATION: FREE TRADE

Emergy calculations can illustrate free trade and indicate some solutions to its problems.

Table 4. Comparison of Emergy Use Per Person Among Nations.

State or Nation	**Emergy Use E22 sej/year**	**Population E6 people**	**Emergy Use/person E15 sej/year**
Canada	268.0	30.5	87.0
Australia	138.0	19.4	71.0
United Kingdom	287.0	58.8	48.7
Russia	703.0	145.0	48.4
U.S.A.	1150.0	280.0	41.1
Switzerland	25.4	7.2	35.5
Japan	360.0	127.0	28.4
Chile	28.0	14.8	18.9
Saudi Arabia	55.8	22.0	25.4
France	144.0	59.8	24.1
Italy	126.5	57.5	22.0
Germany	153.0	83.0	18.4
Brazil	277.0	161.0	17.2
South Africa	73.9	43.2	17.1
Portugal	17.6	10.5	16.8
Argentina	45.2	35.1	12.9
Uruguay	3.1	3.2	9.6
India	266.0	1029.0	9.5
Paraguay	4.8	5.2	9.3
Mexico	61.4	76.8	8.0
China	917.0	1284.3	7.1
Indonesia	125.0	230.0	5.4
Bolivia	1.9	7.8	2.5

Table 4 shows the inequities in emergy use among countries. Since the Industrial Revolution, and even before, trade has usually moved resources from countries with natural resources to countries with industrialization. Much discussion is going on about globalization and whether free trade agreements are equitable. Will they help bring more emergy to the poorer countries?

Table 5 is a summary of the emergy per dollar of each country – how much emergy each dollar (internationalized) will buy in that country.

Table 5. Comparison of Emergy-Dollar Ratios Among Nations.

Nation	**Emergy Use E22 sej/year**	**Gross Economic Product x E9 $/year**	**Emergy/Dollar E12 sej/$**
China	917.0	979.9	9.35
Indonesia	125.0	145.0	8.60
Paraguay	4.8	6.3	7.68
India	266.0	442.0	6.03
Russia	703.0	1200.0	5.90
Chile	28.0	54.9	5.10
Brazil	277.0	58.0	4.80
Canada	268.0	599.0	4.50
Australia	138.0	340.0	4.05
Mexico	61.4	186.1	3.30
Bolivia	2.0	6.4	3.03
Uruguay	3.1	12.2	2.52
Saudi Arabia	55.8	241.0	2.30
United Kingdom	287.0	1390.0	2.06
Portugal	17.6	91.5	1.90
Argentina	45.2	297.7	1.52
Denmark	17.8	123.0	1.45
USA	1150.0	9940.0	1.16
France	144.0	1400.0	1.03
Switzerland	25.4	270.0	0.95
Japan	360.0	4500.0	0.80
Germany	153.0	209.0	0.73

The emergy-dollar ratio is the average amount of emergy that can be bought for one international dollar. It is calculated by dividing the country's total emergy use by its GNP in international dollars. It is the buying power of the dollar in each country. Americans traveling in Brazil or China, get more for our money than we do at home. In France and Japan we pay more. When Brazilians or Chinese come to the US goods and services are more expensive.

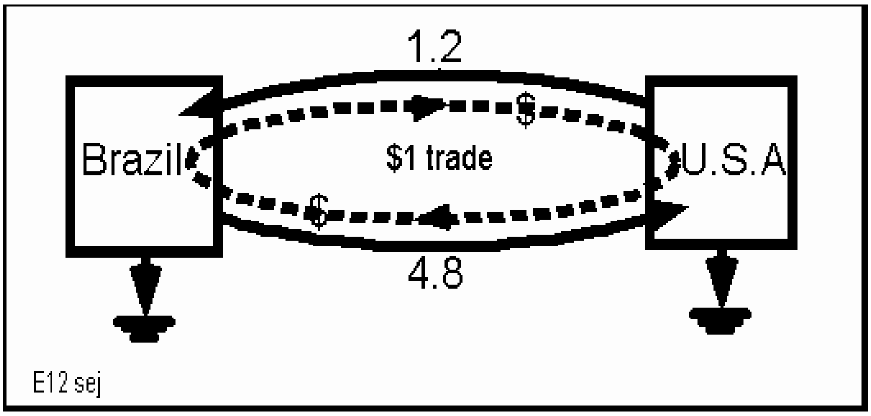

Figure 7 is a trade example which shows how emergy calculations can be used.

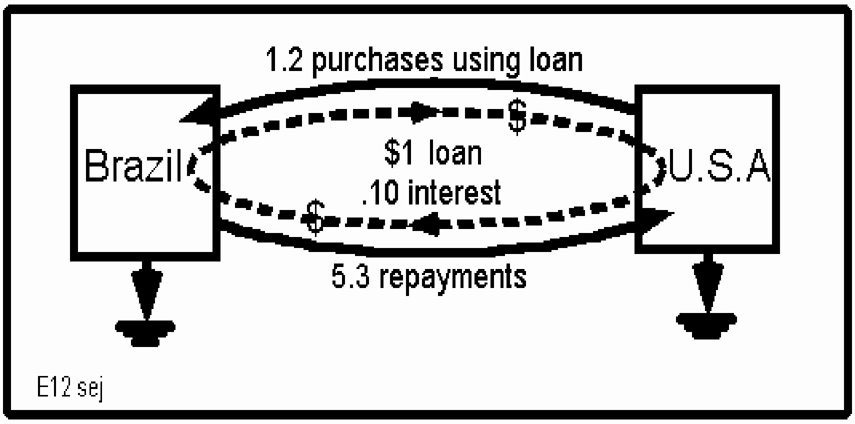

Figure 7. In an even dollar trade the USA can buy 4.8 E12 sej from Brazil; whereas Brazil can only buy 1.2 E12 sej from the USA.

On an even money basis this trade is equal and fair. But when looked at from an emergy view, the USA is getting a four-fold advantage. When you consider a loan from the USA to Brazil the inequity is more obvious. Brazil owes $280 billion to the World Bank. In emergy calculations it has already been paid back. Borrowing countries know the present system of loans seems unfair, and these comparisons show it is.

So, until we can persuade national decision-makers to use emergy trade calculations, countries should plan to trade with other countries that have similar or higher emergy-$ ratios. The way to bring equity to international trade, is to base it on emergy not dollars. Would this make the countries of the world less competitive – and more prosperous ?

7. INTERNATIONAL MINIMUM EMERGY WAGE

With a goal of more equity among poor and rich countries we propose an international minimum wage. It could be called an international minimum emergy wage. Each country's minimum would be based on how much emergy can be bought for a dollar in that country, roughly the emergy/dollar ratio. This idea is left for further study.

8. WAR AND SHARED INFORMATION

Many people believe that military fighting is sometimes necessary to solve international problems. Others believe that the power of non-violent action produces stronger and more lasting solutions. The systems ecology way to attack a problem like this is to look at the next larger system. If you look at the world of nations you see that information is more powerful than weapons and fighting. Information has the highest value, most emergy, and greatest power. Shared information has even more power. In potential wars we can calculate how much emergy power each country has and then predict who's going to win. Calculations like this should encourage the countries to make peaceful agreements.

For example, the USA had the power in WWII to win against Germany and Japan. However, in Vietnam we had less power and could not win so far away. Emergy analysts could have calculated that, but we don not yet have the ear of enough policy makers.

We can consider the present-day war in Iraq. There are probably several reasons the USA went into Iraq. We want control of the oil, and we also want to maintain political control of the basic resources of Middle East. The US administration seems to have a desire for imperialism and power. President Bush talks about a vision of changing the whole world to democracy and his values.

Many tried to settle the Iraq problem with shared information through discussion in the UN. But, the US leaders were too impatient. They believe military might is stronger than discussion and consensus. The US can overwhelm the Iraqis militarily, but it is doubtful we can win the peace. The information war in Iraq and the other middle Eastern countries will take much more positive shared information. Shared information is spreading to cause changes in world views and actions. The 9-11 attack, this war in Iraq, and other terrorist actions are helping to make us aware of increasing envy of the wealthy. Information is also reinforcing the views of the poor that their situation is not fair, that there are great inequities in emergy per person and maybe they can do something about it. Al-Jezeera TV in Qatar broadcasts the Eastern view; CNN shows the Western. We need both on all the TVs. The Internet World Wide Web will probably be the way global information spreads everywhere. It is all over the world, even in countries which control their media.

9. CONCLUSIONS

The overall goal, using another basic principle, is to maximize the power of the global system. To use ecological language, the world is acting like an ecosystem in the early competitive stage of succession, rather than a stable climax system with cooperation and sharing. The two most important subjects which need shared information to maximize power are emergy equity and religion. The goal of equity is a basic minimum emergy for every person. Religious information is very high emergy with much power. We must use shared information to discourage competition and create tolerance. Each person or group can have their own beliefs, but they must be accepting of others. As fossil fuels are used up, there is one optimistic idea. With less fossil fuels we can produce less military hardware. We can concentrate on ideas and sharing information. Shared information is high emergy and high quality, and it takes less energy to make and sustain. If these problems of migration, trade, international capitalism, war and religious intolerance are not fixed, we can crash. So we all must work at making the coming down slow and prosperous and happy.

NOTE

You can find more shared high quality information at the Center for Environmental Policy at the H.T. Odum Center for Wetlands, University of Florida, Gainesville.

References

Campbell, Colin J. Petroleum and people. Population and Environment; Nov. 2002; 24,2; SBI/INFORM Global pg. 193.

Campbell, Colin J. 1997. "Depletion Patterns Show Change Due for Production of Conventional Oil" Oil and Gas J. (Dec.):33-39l

Odum H. T. and E. C. Odum, 2001. A Prosperous Way Down, University Press of Colorado, Boulder, Co.