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I

THE APPROACHING SUMMIT

The summit of our civilization is just ahead, so we all need to consider how our lives will change and the plans we should make accordingly. Part I considers the present condition, controversies about the future, and the general idea that a natural turndown and descent can be *prosperous.* After Chapter 1 introduces the book, Chapter 2 shows our present condition with recent data, and Chapter 3 reviews the widely different writings of other authors about the future.

Perhaps then readers will be ready for the chapters on systems principles in Part II to explain what is happening. In Part III we use those principles to recommend policies.

1

INTRODUCTION TO THE WAY DOWN

Like a giant train, the world economy is slowly cresting its trip up the mountain of growth. It may be ready soon for its long trip down to a more sustainable lower level. The developed nations that were leading on the way up are poised for leading again, but this time down. In Chapter 1 we explain the concept of *A Prosperous Way Down,* pointing to the later chapters on our present condition, the views of others, the principles by which the global system is understood, and the policies required for society to adapt. We also explain why we need to think with systems diagrams, the analogies with ecosystems, our summary of public skepticism, and the flip in attitude that is likely. Recall the story for children about the little train going up the mountain (Figure 1.1): "I think I can; I think I can." Then coming down: "I thought I could; I thought I could."

THE PROSPEROUS WAY DOWN

Precedents from ecological systems suggest that the global society can turn down and descend prosperously, reducing assets, population, and unessential baggage while staying in balance with its environmental life-support system. By retaining the information that is most important, a leaner society can reorganize itself and continue making progress. The situation is analogous to the human brain, which regularly dumps less essential information in short-term memory while gathering what is important for the long-term memory.

The reason for descent is that the available resources on Earth are decreasing. Each year more effort is needed to provide the fuels, water, wood, fish, soil, food, electric power, and minerals on which everything else is based. More and more of the economy goes into concentrating what remains with less left for the private lives of people. More

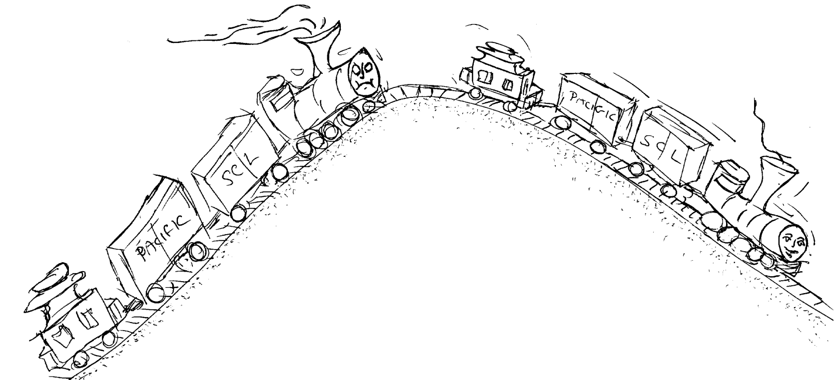


Figure 1.1. The Story of the Little Train (Ann Odum).

and more of the resources supporting the developed nations are diverted from people in other countries by the global economy. The present levels of our urban civilization cannot be sustained indefinitely on the worldwide declining concentrations of resources (see Chapter 10).

Make no mistake, this is *not* a proposal for less growth. It is recognition that general systems principles of energy, matter, and information are operating to force society into a different stage in a long-range cycle. One set of policies is needed for the transition and another set for the descent. We can also look way ahead at a lower energy period when environmental resources accumulate again.

In spite of tendencies toward economic competition, global cooperation has increased. Global unity was improved by teaching ideals of mutual respect and equitable trade. Resurgence of local characteristics, customs, and environmental adaptation has also occurred, helping people to find a smaller group identity in a large complex world. Strengthening local culture is desirable, provided it is accompanied by mutual respect and shared belief in cooperative working relationships among those who are different. The global significance of the 1999 Kosovo war in Yugoslavia was to establish the principle that military aggression against people who are different is no longer acceptable to the majority of nations.

That the way down can be prosperous is the exciting viewpoint whose time has come. Descent is a new frontier to approach with zeal. The goal is to keep the economy adapted to its global biophysical basis. We have to abandon some of our useless diversions. If everyone understands the necessity of the whole society adapting to less, then society can pull together with a common mission to select what is essential. Presidents, governors, and local leaders can explain the problem and lead society in a shared mission. Millions of people the world over, if they see the opportunity, can be united in the common quest for a prosperous way down. The alternative is a world of selfish battles for whatever resources remain.

UNIQUE BASES FOR EXPLANATIONS

This book is different because its explanations about society come from the general scientific concepts that apply to *any* system. These concepts suggest the constraints on the future to which human society will have to fit. In the language of general science, the system of human society and its environment is self-organizing. Through the initiatives of millions of people all sorts of things are tried daily. Those that work are copied by others and become part of the mainstream system of society.

The processes of nature also self-organize with restless testing. The most familiar example is natural selection among species, but reinforcement of what works also occurs in other kinds of systems and on different scales. Thus the global pattern of humanity and nature is a combination of the stormy atmosphere, swirling ocean, slowly cycling Earth, life cycles of living organisms, ecological adaptations, and the complex actions of human society and its economics.

Theory and research now suggest that many, if not all, of the systems of the planet (and the universe) have common properties, organize in similar ways, have similar oscillations over time, have similar patterns spatially, and operate within universal energy laws. If so, it is possible to use these principles in advance to select policies that will succeed. In other words, humans can use their intelligence and social institutions to avoid some of the wasteful mistakes caused by trial and error, doing a better job at evolving a prosperous world within the constraints of nature.

Unfortunately, we have no procedures for proving that principles are general except to keep testing them in new situations. When a principle is successful in explaining outcomes for many examples, it begins to be more and more trustworthy. The general principles offered in Part II have been applied widely, and evidence has come from many different disciplines. Hopefully readers will recognize examples from their own experiences.

Views and Scales

In Chapter 3 we review the wide range of ideas of other authors about our society. Many of their views are consistent with principles in Part II. What we offer is a way to tell which of the myriad of scenarios from futuristic imaginations are appropriate and likely for the times ahead.

Some of the authors try to find causes in short-term, small-scale processes and mechanisms such as: interactions of economic markets, cultural reactions, global capitalism, national policies, atmospheric changes, religious movements, local wars, technological innovations, and so forth. But the general systems view is that the larger-scale pattern selects what is workable from the trials and errors of the smaller scale. The regime prevails because it maximizes the performance possible for those conditions.

Often implied is that humans can select whatever destiny is desirable—a half-truth. The new hope of our time is that the designs in society that will ultimately prevail can be found more rationally by using large-scale principles more, wasteful trial and error less. The new global sharing of information and ideas makes it possible for billions to learn about world pulsing, and to embrace a new faith that coming down is OK.

In this book we recognize the way the important controls on any phenomena come from the next larger scale, determining the main cycles of growth, turndown, catastrophes, and regimes of energy and material to which society must fit. This is a type of scientific determinism. The paradox is that most scientists restrict their deterministic beliefs to the realms of their specialties. When it comes to society and politics, many share the public's view and deny that large-scale principles control phenomena.

Emergy Evaluations

Many futurists write of processes and change qualitatively, although economic data are sometimes cited. In this book we use a new measure—*emergy*—to evaluate the main inputs, products, and accomplishments of our world on a common basis. It is a special measure of the previous work done to make something, whether the work was done by natural processes or by humans.[1] For example, emergy values of exchanges explain why well-meaning international investments and loans have been crushing underdeveloped countries.

Ecosystem Analogy

Forests, lakes, grasslands, coral reefs, sea bottoms, and so forth are ecological systems (ecosystems). They operate on a smaller, faster scale than civilizations, and humans can more easily see the essence of their complexity in relation to the controlling principles of energy, materials, and information. Like civilizations, they have growth cycles, periods of weed-like growth, and periods of high complexity and diversity analogous to human pluralistic societies. Ecologists have a range of views. Those at one extreme see many random processes and seething interactions of species struggling for existence. Those with our view see a high degree of self-organization involving causal interactions through intermittent pathways best generalized with energy systems principles.

Important for our purpose in this book, many ecosystems grow and decline in cycles that are repeating and sustainable. For example, lake ecosystems have daily and seasonal cycles. Forests have cycles involving many years each. H. K. Okruszko[2] named the stage of peatland decrease as *decession,* the opposite of *succession,* the development stage. The normal cycle of some ecosystems includes sharp "destructive events" like fire or consumer epidemics, which are beneficial in the long run, because they accelerate downsizing to the next stage. Dynamiting old buildings for urban renewal is analogous to the ecosystems' destructive events. Thus we use ecosystem comparisons for insight into the larger-scale cycles of our own society.

Network Diagrams for Understanding

Although the call for a systems view is widespread, most people discuss the problems and solutions with verbal concepts that don't give the mind an understanding of connections. Often people won't take the time to study network diagrams that are necessary to visualize causes. The late economist Kenneth Boulding, a brilliant writer, reviewed our earlier book *Energy Basis for Man and Nature* and wrote that it was not necessary to look at the diagrams. But understanding systems requires a language that shows how the connections work. For an overview of the complex system of humanity and environment, the human mind needs the comprehension that comes from seeing the connected functions of the network simultaneously in the mind's eye.

For human understanding the network first needs to be simplified by aggregating the complexity into the main process and parts that are important. Getting the system view in mind helps in understanding the way structure is related to function. You can see parts, wholes, and consequences at the same time, carrying a systems image in memory.[3] Since basic mini-model configurations apply to different kinds of systems on all scales, a person accumulates ways of transferring understanding to new situations.

Policy from Mini-models

Many–if not most–people trained in science learn about separate parts and relationships, expecting computers to synthesize what the combinations will do. But carrying a simple mini-model of a system in mind is a different methodology from expecting computer simulation of large complex models to generate something of which the mind understands only a part at a time. Policy about complex systems is usually made with whatever synthesis word-models provide. Better policies can result if simple mini-model diagrams are kept at hand to visualize causes.

Scale of View

The human mind is like the zoom microscope, able to change focus rapidly from small scale to large scale. For example, some writers describing the behavior of society as a whole use concepts and language from the smaller scale of human psychology about the behavior of individuals. Sometimes authors use analogies to clarify a point. The authors may mean that the society is the sum of the individual psychological actions. Or the writers may mean that individuals and the society are both examples of the same general systems model. Because words are so all-encompassing with so many alternate meanings, they are not very rigorous for representing systems relationships and many scales.

In Part II of this book we use network mini-models to make points about transition and turndown. Our explanations of how the Earth's economic system works can be best understood by putting the pictorial images of systems relationships in mind.

CONTEMPORARY CHANGE

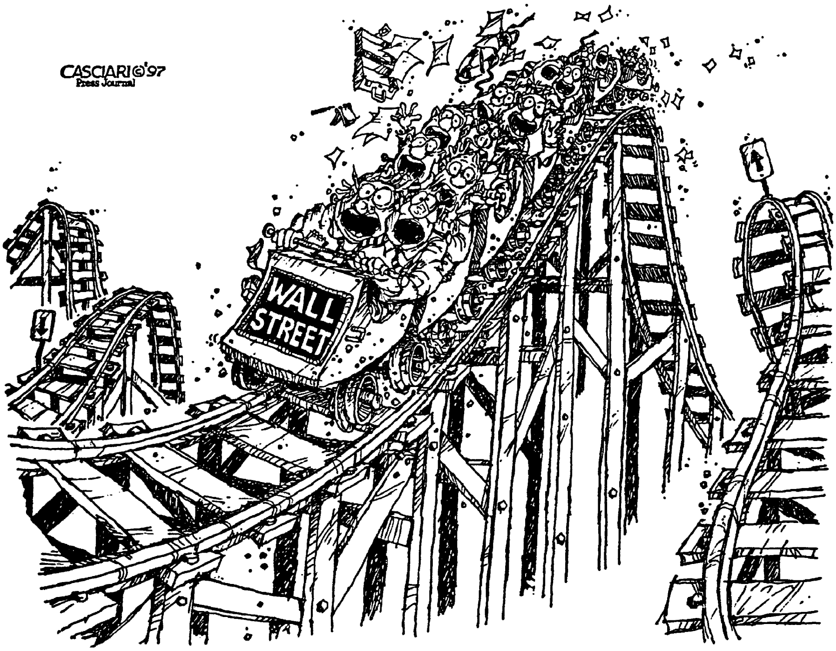
The summit for the global economy ahead is hidden by the surge of affluence in the wealthy sectors of a few countries. But downsizing is already occurring in many parts of the system. This is the start of the long process of reorganizing to form a lesser economy on renewable resources. If we do not understand the principles that are causing the decreases, we won't plan the needed changes. Without a collective mission to adapt, we are more likely to stumble with delay, failures, fear, desperation, conflict, malaise, pestilence, environmental destruction, and collapse.

The Present Reality

Whether the crest in the United States has been reached yet is not clear because short-term fluctuations of the economy mask long-range trends. The annual increases in gross economic product show money circulating more rapidly. Much of it, however, is through finance and stock markets, and circulates without producing real wealth. There are surges in computers and communication but pathological waste of resources in, for example, excess cars. Other measures show important parts of the economy and Earth systems in decline. Recent books on the future and its policies are wildly different. Some warn of crash and others of perpetual boom ahead.

Trends

In Chapter 2, recent trends in resources, population, information, human welfare, and economic states are quoted from various authors and sources. In Chapter 3 (especially pp. 50–53) many of the authors cited look to the future by extending the trend lines on these indices



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of society, usually with properties growing upward. Yet all who know about the causal connections between energy, materials, and growth expect an eventual turndown. The question is when. What is argued is: how many usable fuel and mineral resources are still to be discovered underground? And how much of the present world economy could be supported on the proposed alternative energy sources, most of which have been under intensive research for a half century? Whether turndown is near or to follow later, task forces are needed at local, national, and international levels to plan for transition.

Instead of planning for descent, many writers, journalists, and political leaders encourage a continuation of the established public mind-set on growth that was okay for the time of expanding resource use. For some it is failings in their education; for others it is overfocus on the short range. Nearly six billion people are in denial, and for leaders to speak of a nongrowth period is viewed as political suicide. But the paradigm of growth is a shared global attitude that may switch all at once for all together when the truth becomes obvious through some galvanizing event. Or perspectives may shift gradually as books like this one circulate.

PUBLIC PERCEPTION

Interruptions in fuel supply in the 1970s gave people a momentary glimpse of a resource-limited future. As we cite in Chapter 3, many authors considered how to adapt to lower energy availability. But decreasing before you need to is contrary to fundamental energy principles, as we will explain. In the 1980s the world could be and was still engaged in growth. Plans for descent seemed nutty. When the first draft of this book was written in 1982, "coming down" was considered only by a few as a pleasant, alternative lifestyle to seek as a matter of choice. Publishers did not think their readers would be interested. By the end of the century some decreases began. Some downsizing was erratic, divisive, and competitive, a bitter contrast to the ideal of a prosperous descent.

Not enough people understand the large-scale changes requiring them to change individually. Few have been trained to think about resource limits on the large scale. Few people now believe that principles other than that of the free market controls the overall economy. In the late 1990s the real wealth per person was oscillating even though leaders were still talking about more growth. Inequity, blame, and class consciousness threatened the fabric of society. Many returned to the ways of the nineteenth century, when there was more selfish individualism and competition. Although political pressure to downsize has been directed at government, more–not less–government coordination may be needed to adapt society to the new stages ahead.

Some of the indices of our society (see Chapter 2) had stopped growing by 2001. Perhaps going into the twenty-first century people are more open to explanations of the root causes for change. Many are not happy, blaming others or fostering greed in the economic system. They may be ready for the concepts and policies given here that can make the inevitable descent better.

One New York publisher explained why a trade book on future policies based on energetics and systems principles probably would not sell. He said "people don't believe scientists have any special insight on the future." They don't believe humans, economy, and environment follow collective scientific principles. Especially where people are raised with an emphasis on human freedom and choices, the public does not feel controlled. Many have faith in free market economics, because explosive capitalism fits the stage of weedy growth that has lasted for two centuries.

An important quality of our social species is the ability to reprogram ideals and objectives when it becomes apparent to the majority that it is necessary. When growth is possible, then it is necessary, and everything that goes with the exploitation and competition of expansion stages is regarded as good. Then when adapting to descent is necessary, everything that goes with making that stage efficient becomes good. We even slant history with ideals of the present. People already write about the fanatic, zealous, and sometimes ruthless exploitation used for expansion in the nineteenth century as evil, but it was not the public view then. Exploiters were heroes. It is fascinating that changes in attitudes appropriate for a time of leveling and transition, such as complexity, cooperation, diversity, and environmental adaptation, are already being recognized as new ideals.

According to one principle, systems help maximize their performance by the accumulation of stores of materials, energy, or information, to be followed later by a sharp pulse of growth by a using consumer. This mechanism of change applies to public opinion too. Need for a change and consciousness of it accumulate bit by bit in more and more people until a threshold is reached when the whole group discusses and switches attitude, using the energy from the unified focus to change institutions. Perhaps we are now in the stage of accumulating new attitudes for turndown and descent.[4]

Many books try to enlist people in social movements with the assumption that change depends on human choice. But it may be vice versa, that social change is set by events in the resource-civilization cycle. If readers will stay with us long enough to consider the principles (see Chapters 4–8), they may be open to the predictions and policies that might otherwise seem radical.

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The prosperous way down☆

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Abstract

Principles that appear to govern all systems including human societies were used to consider the time of economic descent ahead. These include the energy laws, the emergy concept, the maximum empower principle, the universal energy hierarchy, the conservation and hierarchical distribution of materials, the spatial organization of centers, and the pulsing paradigm. Population and cities, energy consumption and climate change, agriculture and environment, information and electric power, capitalism and economic policies, structures and materials, human life and standard of living are dealt with in this paper as interconnected aspects of the same problem, i.e. the necessary descent phase of human economies, due to decreasing resource base. We expect much of the resource use, culture and public policy appropriate for the growth period to be replaced with a new set of ethics and policies affecting each scale of time and space during descent. Decisive changes in attitudes and practices can divert a destructive collapse, leading instead to a prosperous way down.

1. Introduction

Let us start with the premise that resource scarcity and rising costs cause the global economy to contract. Let us not be concerned here with the timing, but consider what can be expected and what our

☆ A preliminary version of this paper was presented at the International Workshop 'Advances in Energy Studies', Porto Venere, Italy, May 2000. As such, it was intended as a way to provide provocative hints for discussion to the Participants. The latter, invited by the Organizers, were among the leading experts in the field and did not require too many details. Though the paper is now part of a Special Issue of this Journal dedicated to the Workshop results, we preferred to keep the style unchanged, not to lose the original feature of a talk given to experts, in order to stimulate debate and—why not?—controversy.

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adapting strategies should be to conditions that force descent. There are many new words being used for this future scenario, such as *decession*, the opposite of *succession*.

The expectation of *general systems concepts of self-organization* for any system is an alternation between slow production, growth and succession followed by a pulse of consumption, descent and decession. Pulsing on each scale is an accumulating build up of products converged to centers, followed by descent with sharp, short diverging dispersal. Many assume that the only way down is to crash and restart. But many systems *program orderly descent and decession* that is followed later by growth and succession again. For example, in the past, ecosystems and human cultures in northern latitudes expanded and contracted seasonally. They decreased populations, stored information, and reduced function with such mechanisms as spore and seed formation, hibernation, migration, and staging inactivity and rest.

We recognize four main stages of the pulsing cycle: (1) *growth on abundant available resources*, with sharp increases in a system's population, structure, and assets, based on low-efficiency and high-competition (capitalism and monopolistic overgrowth); (2) *climax and transition*, when the system reaches the maximum size allowed by the available resources, increases efficiency, develops collaborative competition patterns, and prepares for descent by storing information; (3) *descent, with adaptations to less resources available*, a decrease in population and assets, an increase in recycling patterns, and a transmission of information in a way that minimizes losses; (4) *low-energy restoration*, with no-growth, consumption smaller than accumulation, and storage of resources for a new cycle ahead.

The pulsing paradigm has always been in front of our eyes. Forest ecosystems never did anything different, with short pulsing cycles that we were able to see and understand. Deciduous trees bloom and grow in spring, make fruits and seeds (stored information) in summer, lose their leaves in autumn (for recycling by soil microorganisms), and seem to sleep and recover in winter-time, when available resources (solar energy) are less. On a longer time scale forests develop, grow, and then either senesce or are obliterated by very natural disturbances. Very similar resource-dependent patterns characterize all the other living species on Earth, including humans. Human societies grow and decline. After earlier studies of oscillating population models, Holling [1] used a now well-known 'figure 8' diagram to generalize about 'nature's cycles'. The Roman Empire is now over and through its demise we may be able to recognize this trend. It took more than one thousand years for the whole cycle to run and about 300 years for the descent only. The longer pulsing 'wave-length' makes it difficult for us to recognize the cycle of which we are part, while recognizing the shorter pulsing cycles of ecosystems. Tainter [2] gives us so many examples of once-proud and enormous civilizations that remain only as stones under desert sands or the vegetation of jungles.

2. Emergy, empower and pulsing

The most abundant source of energy on Earth is sunlight, but because it is spread out in time and space, it is low quality compared to the many other forms of energy on Earth derived from it. Many solar joules are required to make other kinds of more concentrated energy, the kinds that humans need. It is convenient to express all other kinds of energy on Earth in terms of the sunlight energy required directly and indirectly. For this we introduced a new word in 1983, emergy, spelled with an 'm', defined as 'the available energy of one kind (usually solar) that has to be used up directly and indirectly to make a product or service'. The unit of solar emergy is the *solar emergy joule* (seJ), to distinguish it from the *regular* joule (J) and point out a different quality assessment based on a donor-side point of view. The solar emergy per unit product or output flow is called ‘solar transformity’, with units of seJ/J.

Energy transformations generate hierarchies over production chains similar to the well-known food chain in ecosystems. In self-organization, items that require more energy would not be produced for long if they did not have a positive effect to the larger system justifying the resource (emergy) required for their manufacture. As a consequence, designs are reinforced that maximize power output possible from the resource available [3,4]. The system can then draw in more resources, produce more and out-compete alternative patterns that reinforce less. In other words, successful systems develop structures that maximize useful resource production and consumption, also by feeding back matter and information.

This general design is found in biochemical reactions, weather systems, seas, geological processes, ecosystems, relationships of stars, and appears to apply to human economies as well. Organization for maximum power is observed in all scales simultaneously. The biochemistry within the human body is self-organizing for maximum performance minute-by-minute, while the whole human is participating in the self-organization of the economy on a much larger scale.

Where several levels of energy hierarchy are involved, ‘maximizing power’ can be misleading because it might imply that priority goes for increasing energy flow through the lower levels, which may have more energy. Instead, if the Lotka principle is restated via the emergy concept as the maximum empower principle [5], then the flows at all levels of the energy chain can be equally suitable for reinforcement. The revised statement is: ‘in the self-organizational processes, systems develop those parts, processes, and relationships that maximize useful empower’. If the maximum empower principle is recognized as also applying to human economies, then its statement for policy is: ‘Choose alternatives that maximize empower intake and use’.

Is the pulsing paradigm consistent with maximum empower? It appears to be a general principle that pulsing systems prevail in the long run [1,6,7] perhaps because they generate more productivity, empower, and performance than steady states or those that bloom and bust. Pulsing prevails because operations that pulse transform more energy than those at steady state. Apparently, an alternation of production and consumption provides a better long-run coupling of energy intake for maximum empower than a steady state can provide. There are abundant examples of the pulsing pattern of human cultures in their use of environment. Judging from history, human cultures contain the ability to switch from a regime that uses up stored resources to increase population, technological innovation, and civilization, to a quiescent regime in which the environmental reserves of forests and soils regrow. The 500-year cycle of the rise and decline of Mexico’s Mayan civilization may be such an example.

We deal in this paper with changes that accompany descent, either we adapt with deliberate process or have these changes forced on us with damaging repercussions. They are hereafter described and interpreted in the light of the pulsing paradigm, the emergy theory and the maximum empower principle, deeply rooted in General Systems Theory [8] and thermodynamics [9,10]. When maximum empower and natural selection are operating, maximum efficiency as defined in classical textbook thermodynamics is no longer the goal. As environmental conditions change, the response of a system will adapt by *optimizing*, and not necessarily maximizing, its efficiency, so that maximum power output can be maintained. In this way, systems tune their thermodynamic performance according to the changing environment. Although we cannot predict how societies will react, we can use quantitative resource evaluations [11,12] to characterize what is possible. For each of these changes, some suggestions are made that could make descent less traumatic and more prosperous. Many of the changes are in progress.

3. Population and relocation

3.1. Necessary population reduction

To sustain a reasonable standard of living (emergy per person), population has to be reduced at the same rate as the rate of resource use. Since population growth momentum may overshoot the time of descent, to sustain the emergy per person requires rapid decrease in population. Either people reproduce less or are reduced by starvation and disease like that evident in Africa. Available resources allow a population to grow until it becomes crowded and drains those resources. Then because of reduced resources and negative factors of crowding, the population declines until resources accumulate again so that the cycle can repeat.

In most developed countries couples are limiting their families to one or two children. This decision is made by each family on the basis of the cost of raising and educating children. Multiplied by many families this decision adds up to a nation-wide reduction in reproduction. Populations in these developed countries would be decreasing except for immigration.

In the underdeveloped world, populations are still increasing. It has been suggested that the most effective population control in poorer nations is to give women the rights to property, employment, and the means to start their own small businesses. The distribution of birth control devices is also necessary, but cannot be the only means for stabilizing or decreasing population [13]. The link between population, fertility and development from a gender perspective has been dealt with in many United Nations documents [14] and important suggestions can be found in the Beijing Declaration and Platform for Action of the United Nations Fourth World Conference on Women, Beijing, China [15].

3.2. Decrease in urban concentration

The extreme concentration of economic enterprises and people in cities is based on cheap fossil fuels. Concentrations and populations are many times greater than can be supported by the surrounding landscape alone. The city's roots in the landscape are now overwhelmed by activity running on fuels, electric power, and their technology. Civilization all over the world became more similar in the 20th century because of a common energy basis. As fuels become less available and cost more, cities have to diminish, eventually to the size compatible with their support area [16,17]. Some industries are already moving to areas where there is more space, cleaner air and water, and land for workers' housing. Reintegrating cities with their region of support and influence may help solve severe urban problems while preparing those cities for the decentralization expected in the time of descent. We may expect decentralized cities to have less-intensive fuel consumption, less transportation, less strip development and advertising, a smaller percentage of a region's population, a better cycle of materials between the city and its environmental surroundings, a longer rotation of building and renewal, and a more efficient spatial pattern.

To deal with the changes expected, the governments of cities and counties need to be combined so that an area and its population centers are managed and taxed as a single system. Private and public enterprises may develop that use the abandoned urban structure to reconstruct smaller less concentrated centers.

4. Policy on fuels

4.1. Eliminating wasteful consumption without reducing empower

To simply limit resource use is not a useful policy since it goes against the maximum empower principle of self-organization, which dictates the maximization of energy and resource flows through all hierarchical levels of a system for it to be sustainable. But limiting luxury and wasteful uses allows resources to go into productive functions and is adaptive. Thus, measures to limit unnecessary horsepower stimulate the economy, whereas taxing or limiting useful resource uses is not a viable option [12], since it forces the system to decrease its resource base, affecting use and misuse.

4.2. Declining dominance of automobiles

Rising fuel costs and general pressure for greater economic efficiency is likely to reorganize the automobile cultures of the developed nations. Societies where automobile use is intensive 'combine massive resource requirements (energy, land, materials), massive environmental impacts (land use, materials use, air pollution, wildlife destruction, noise, safety), massive economic forces, massive disruption/reshaping of culture and the way humans interact with one another, fundamental, strong human motivations and wants, and powerful feedback-rich dynamics in its penetration into the market' [18]. Descent policies may start from reduction of unnecessary horsepower, followed by reduction of autos. Cars for individuals cause cities to spread out, commerce to organize in strip development, and people to live away from their jobs. Not only is there a waste in the excess use of fuel and machinery, there is a waste in the organization of the landscape and the commuting of drivers [19]. Private cars save individual time, but other measures can substitute including more use of communication in place of transportation, people moving closer to work, and more shopping on line.

4.3. Global greenhouse climate changes

There are current efforts now to reduce greenhouse gases that are changing the climate, most of them referring to the so-called Kyoto protocol [20]. Suggested ways to help without reducing economic activity include reducing private car horsepower in developed countries and pushing a global effort to reforest the depleted lands of undeveloped countries, although there is significant uncertainty about the time needed for these measures to be able to restore the CO_2 balance. As soon as global fuel consumption begins to decrease (as its scarcity and costs increase), the earth processes of carbon-dioxide uptake will start to restore a balance between carbon-dioxide release from fuel consumption and carbon-dioxide uptake by eutrophic plant photosynthesis, the carbonate buffer of the ocean, the alkaline soils, and the weathering of rock.

4.4. Energy conservation

Many believe that new sources of energy are likely to replace in a short time the declining fossil sources. This is a controversial issue, since due to the cost of materials and services most solar energy technologies are not yet competitive. Solar energy is a diffuse source and its exploitation requires it to be concentrated and converted. Even if some solar technologies seem to be developing faster than others (e.g. wind), they are unlikely to supply sufficient electricity or liquid fuels to sustain the present high per capita rates of consumption from renewable sources, let alone those growth would require.

Energy conservation is more rewarding. Measures to save energy in the use of appliances—for example, better insulation for houses, more efficient refrigerators, and heat pumps—often yield net emergy even though the energy-saving equipment adds cost. Some efficiency measures are also not economically competitive because they cost more. However, the net emergy of fuels saved is so great, it may make a net benefit to society to provide a financial subsidy such as tax relief for fuel conservation.

Solar energy through agriculture, forestry, and aquaculture can in principle supply each of the necessities: food, fiber for clothing, materials for housing, heating, fuels for transportation, chemical stocks, etc. But there is not enough sunlight to do them all at current levels without the fossil fuels. For the times ahead when fuel use is decreased, policies may be needed to allocate parts of the solar landscape to each of the functions as necessary to keep the economy in balance.

5. Environment and agriculture

5.1. Increase of lower intensity agriculture

The inverse relation of resource exploitation intensity and efficiency has been pointed out by many authors worldwide questioning the possibility of a sustainable food production based on increased technology and non-renewable fuel use. In addition to the day-by-day increasing scarcity of fossil fuels, it is the intensity of agricultural production itself that degrades the potential of land for further agricultural production because of soil erosion and compaction [21]. As a consequence, rising fuel costs and the need for preserving the quality of soil will force agriculture toward a lower intensity with less technology, fertilizer, and pesticide and more labor, provided by people leaving the cities where employment is decreasing. Diverse crop varieties that are more self-sustaining will have to be restored, even though their unit productivity may be less.

5.2. Changed role of environment

During the time of fossil fuel based growth, there was matching use of environmental resources, water diversion, soil loss in industrial agriculture and stripping of old growth forests. Over-fishing, forest losses, and depleted soils are already widespread. As the use of fossil fuels decreases, the economy has to shift once again to a smaller, agrarian base. However, during the transition and turn-down there could be frantic, competitive stripping of the environmental stocks needed for maximum production. To prevent collapse, demand on environment has to be reduced and reorganized during descent.

Soils and forests are renewable, but only with slower rotations than operated by our present economy. We can let fields go fallow for seasons, cut and replant forests on renewable cycles, and let swamps build peat and filter to sustain water quality. These are ways to keep slowly renewable materials available.

6. Information and electric power

6.1. Peace and maximum empower by global sharing of information

When essential information is broadly shared on a large scale, it becomes a long-lasting, unifying mechanism. Information sharing can replace the restrictive information competition of growth capitalism. Television and the Internet have the capability of changing the global organization away from military territorialism. If global ethics for equitable trade and sharing information can prevail, global empower and peace can be protected by the information mutualism that maximizes empower. The dangerous alternative is fragmenting societies warring for residual resources.

The problem here is that the global sharing of information takes substantial resources to develop. It may be restricted to those ideals that are important at the global level. Examples of important messages that need to be shared globally are: protecting the purity of the global atmosphere, maintaining cordiality and trade between neighboring countries that are culturally different, and sharing technologies that are useful anywhere.

It has been called a paradox that there is a spread of global information and economics and at the same time an intensification of separate efforts by local groups to hold on to their special languages, heritages, cultures, arts, and religions. There is no paradox, just properties of a developing hierarchy in which people can be effective by being different about what is small scale but united about what is large scale.

6.2. Selected saving of civilized culture

Information seems ethereal and remote from biological and industrial processes. But because information requires many energy transformations, there are limits to the amount sustainable [22]. Even when isolated in compact form, information requires some form of energy as a carrier, such as that in the DNA of seeds, the paper of books, the electromagnetic waves of radio transmission, or the neuroelectrical processes of the brain. Significant resources are needed to copy, store, disseminate and test the existing information, in order to support patterns for generation of new information. Therefore, information capacity declines with diminishing resources. Also, information loses utility and retrievability as it accumulates. Information may be characterized as something that requires fewer resources to save and copy than to make anew. Like the brain, society has to select and condense the clutter of short-term memory into fewer items of long-term memory. The universities are the main institutions with this capability, if enough resources (emergy) are provided to this purpose.

6.3. Priority use of hydroelectric power

To continue the essentials of the world's civilization requires that global information networks be sustained. But this requires a priority in allocating electric power at a time when electric power from fossil and nuclear fuels becomes more expensive. Strip mining for coal will conflict with the need for agrarian production of food and fiber. It seems likely that centers of civilization will reorganize around the foot of mountains with hydroelectric power, thus using the high net emergy contributions of the earth. Hydroelectricity cannot support the present population of earth during the descent time, which confirms the need for decreasing population and downsizing of assets.

Full development of hydroelectric power reduces the food potentials of salmon and other migratory fisheries at a time when there may be overpopulation and shortages of protein foods. One of our watershed evaluations found greater empower in a river's hydroelectricity than in its salmon runs. Since the prosperous way down depends on sharing a global information network, electricity must have high priority. The prosperous way down may well depend on society's ability to give priority to the greater need for geographic coherence of the larger scale.

7. Capitalism

Innovative economic strategies can be derived from jointly applying the pulsing paradigm and the maximum empower principle to economic systems. Growth capitalism strategies were based on abundant available resources, while getting ready for descent requires the recognition that economic systems must downsize and adapt to resource oscillation. Growth is but a cycle in a resource cycle. Since the policy that works depends on the stage in the cycle and the next stage is economic descent, societies must be prepared and self-organize for the descent stage to be prosperous. Policies based on understanding could be the difference between a soft landing and a crash.

7.1. Decrease in growth capitalism

When there are resources to develop, rapid competitive growth of a few enterprises prevails. In ecosystems, this is called eutrophic overgrowth by weeds. In the economy, this is growth capitalism. Those developments with investment loans outgrow those without the more rapid start. When there are few undeveloped resources, a no-growth system of higher diversity prevails because it is more efficient and better at recycling materials. Enterprises with loans to repay are then at disadvantage.

7.2. Descent capitalism

During descent, new versions of capitalism may appear. Enterprises may be initiated to organize the contraction of the economy using the stored assets as the resource for organizing a smaller economy. There are already some specialists at downsizing. In analogous equivalents in ecosystems, new generations are fueled with the storages of a previous annual cycle.

7.3. Decrease in unearned income

During growth, capital earns high interest as enterprises pay back loans and dividends. People with money have large incomes for which they did no work for the system. After growth, unearned income decreases. A system is more efficient if money is paid for real work.

7.4. Change in development policies

When unused resources were available for development, laws developed that maximized competitive capitalism and growth (because monopolistic overgrowth maximizes empower at that stage of succession). Examples are sale and use of public lands for profit; priority rights for mining over surface land use; and corporations given the same constitutional rights as individuals to exploit economically. After growth, such development accelerating laws are likely to change.

As efficiency becomes a recognized priority, measures to eliminate luxury and waste may be recognized in law and policy. A policy suggested for downsizing reduces income of all personnel in place of the common practice now of reducing the number of employees.

7.5. Stock market transformation

When most growth is over and the public realizes the fundamental change, a destructive stock market crash is possible. Some mechanism is needed to program a gradual, non-catastrophic deflation of the money held in stocks and bonds. For example, an economy-wide stepwise limitation of interest and dividend rates could shift money from stocks and bonds to ownership and efficient operation of those productive enterprises with good annual yields.

7.6. Private enterprise with public control

To maximize system prosperity, private production must include public benefit needs in its operation and pricing (not only make the most for the lowest cost to sell for the highest price). Private business can be required to add the costs of environmental protection and social equity costs of recycling materials, restoring land, and replacing destruction. Minimum wages and benefits need to be included in the costs. These costs are not a burden to an individual company if required of all competitors.

7.7. Developing trade equity

Because the money from developed countries buys more real wealth in trade with more rural countries, the present free trade is not equitable (because of differences in emergy/money ratio). It accelerates the weedy overgrowth of developed countries, which is appropriate only in early growth stages. Developing equity (equal emergy in international exchanges) allows more countries to make maximum contribution to global empower [23] Trade treaties can be used to adjust prices, subsidies, foreign aids, information and other types of exchange to be equal.

8. Structure and materials

8.1. Replacing flimsy housing with fewer buildings of quality

In ecological succession where there are unused resources available, the initial structures are flimsy and temporary but effective at maximizing growth. Later they are replaced by larger, substantial, longer lasting, slow turnover assets. A similar evolution of buildings is expected and can be planned. Trailers and frame buildings with short life times will be replaced by those with substantial permanent structure and less maintenance cost, a process that is more advanced in Europe. As soon as populations decrease, there will be excess building space which can be converted into fewer, more permanent structures.

8.2. Reuse, recycle of materials, and recycle to ecosystems

Efficient, maximum production requires that everything be reused or recycled (not accumulating in dumps). The kind of recycle of materials depends on the concentration and quality (transformity). The free market can deal with high quality and concentration, but ecosystems are required for the low concentrations. To encourage conservation and reuse of materials, some manufacturers are being required to take back the materials they used in the packaging of their products. This plan saves materials and reduces waste dumps.

8.3. Communication replacing transportation

We can save the resources and costs of transportation by using more email, phone mail and fax in place of personal trips and standard mail. More jobs can be done on computers at home. These too have extensive energy requirements, but less than transportation with automobiles.

9. Human life

9.1. Minimum standard of living

Systems principles suggest there is a natural hierarchy in the distribution of wealth that is functional. However, there is a minimum basic standard of food, shelter, education, health care and other necessities for each person to be productive.

9.2. Women, children, and work

During descent fewer children are needed but more people will be required to do the work that is less aided by the more expensive fossil fuels. Women can have fewer children and more education for longer careers of productive employment. Societies making these changes promptly will prevail because of their greater efficiency.

9.3. Flexibility regarding sex

The powerful sex drives of the human species are genetically inherited and thus not easily changed. However, sex can be decoupled from reproduction and used more for satisfying the emotional needs for close personal relationships. The rigid mores channeling sex into producing children are already being replaced with attitudes and laws that allow flexibility in sexual relationships and programs of birth control.

9.4. Education for the future

To prepare children for their lower energy future, we must describe and explain it to them. They need to know why it's happening and how they can fit into it. A course on how to see the world as a functioning system should be required. They will need to know how to manipulate information and computers. But, they will also need experiences in practical living, like how to grow edible food, how to repair rather than throw-away, and how to make housing more permanent.

9.5. Family values

Some values and lifestyles have to change with the need for fewer children, decreased family resources, and fewer cars. Children continue to need stable family relationships. Communities can reorganize around smaller neighborhood schools. The ethics of large scale unity needs to be added to the small scale ethics of traditional religions.

9.6. Local societies and pluralism

With less transportation, there is opportunity for more social organization locally and cultural diversification as viewed globally. Developing more separate local cultures is not incompatible with global coherence providing all groups retain the ethic of global awareness, cooperation, and mutual respect.

10. Conclusions

As the global crescendo of information and investments rushes towards the culmination of civilization, most of the six billion people on Earth are oblivious to the turndown ahead. It's time for people to recognize what is happening and how they will be forced by circumstances to adapt to the future.

We know from teaching that many students who hear the story of energy systems causality are profoundly influenced. Now, as signs of downsizing are appearing in our economic life, it is time for everyone to consider fundamental changes in policy and plans. This is not a proposal for less growth. It is recognition that general systems principles of energy, matter, and information are operating to force society into a different stage in a long-range cycle.

If the principles (emergy, maximum empower, pulsing paradigm) are correct and we interpret their application correctly, then our recipes for a prosperous future are a prediction of what society will be forced to consider. If civilization is to progress, it has to learn to advocate the patterns that these principles predict. In the process, a growth culture will be able to change smoothly into a culture of descent. However, history records many systems that crashed instead. Showing a good way down is a call for everyone to think ahead and plan.

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A PROSPEROUS WAY DOWN

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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.

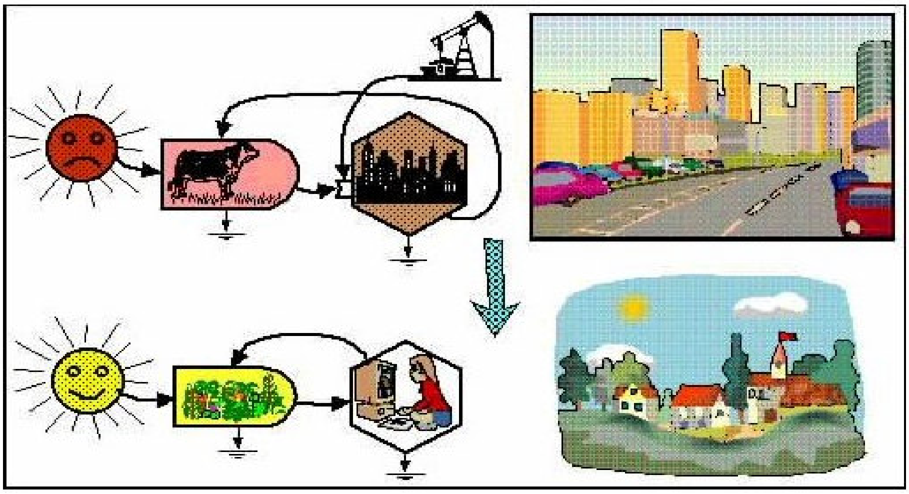

Figure 1. This picture of the trend illustrates the hypothesis with two parts: we are going to live with fewer resources and we can be prosperous and happy with fewer resources.

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).

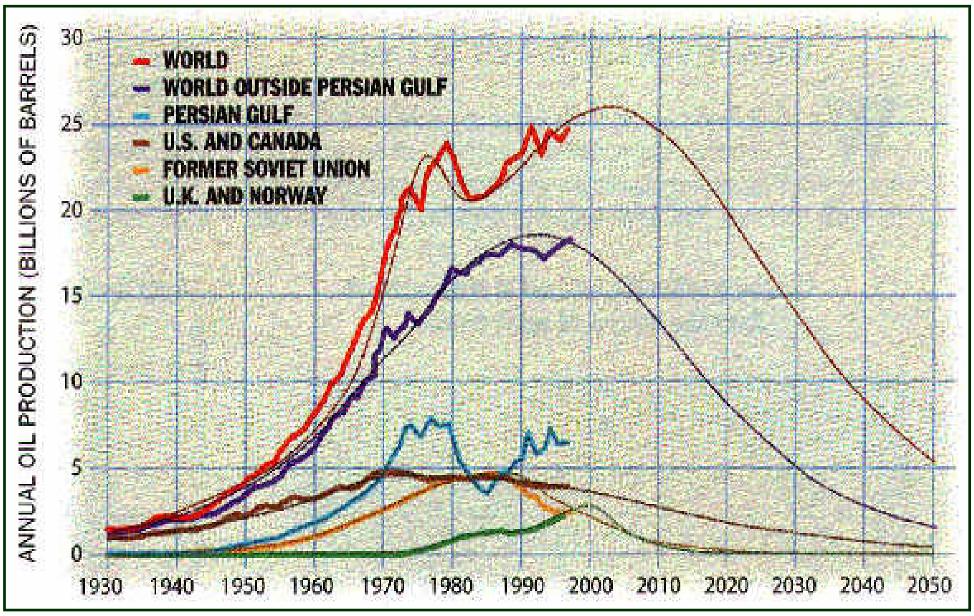

Figure 2. This graph from a Gas and Oil Industry report shows world oil production peaking in about 2004.

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

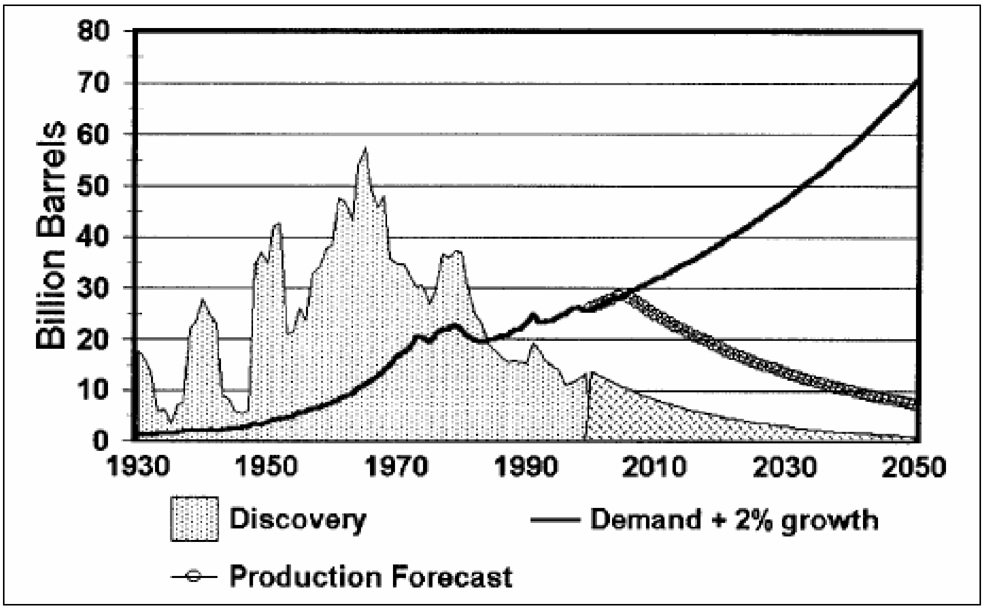

Figure 3. Discovery trend. Oil discovery peaked in the 1960's, when we were finding more than we used. Now, the situation is reversed, meaning that the historic trend of growth of about 2% a year cannot be maintained as we consume our inheritance from past discovery.

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.

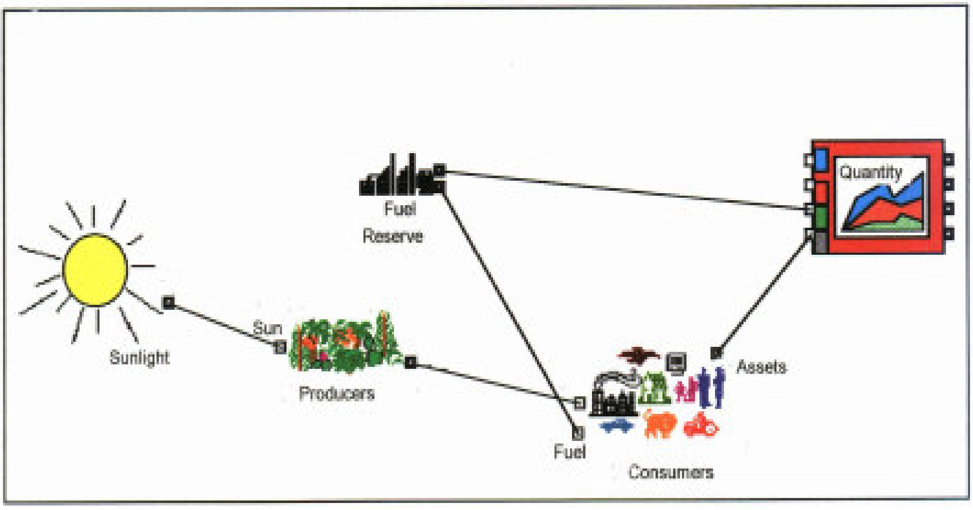

Figure 4. A computer model of the economy showing economic consumers using the two kinds of energy sources: renewables (sunlight) and nonrenewables (fuel).

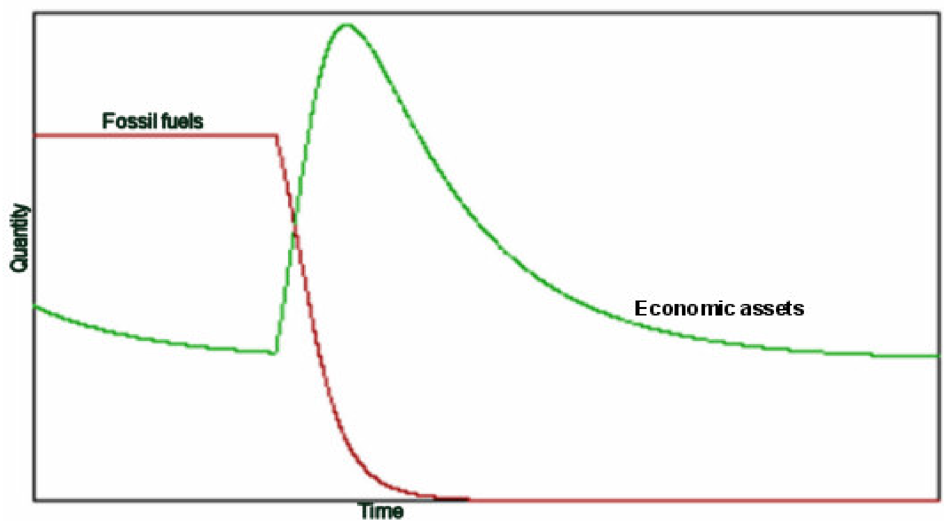

Figure 5. Before fossil fuels were used, the economy was supported by the renewable sources. When fossil fuels began to be used, economic assets grew rapidly. As fuels are used up, economic assets will again be supported by the renewable energy sources.

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.

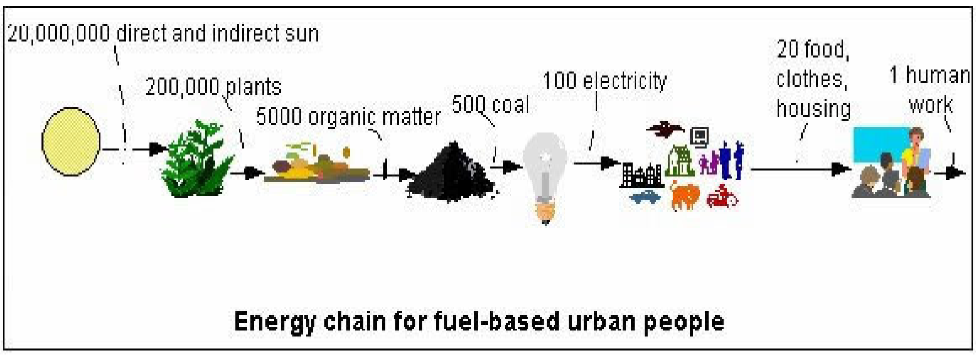

Figure 6. 20 million joules of direct and indirect sunlight are used to produce each part of this energy chain. 20 million joules is the solar emergy of each component.

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

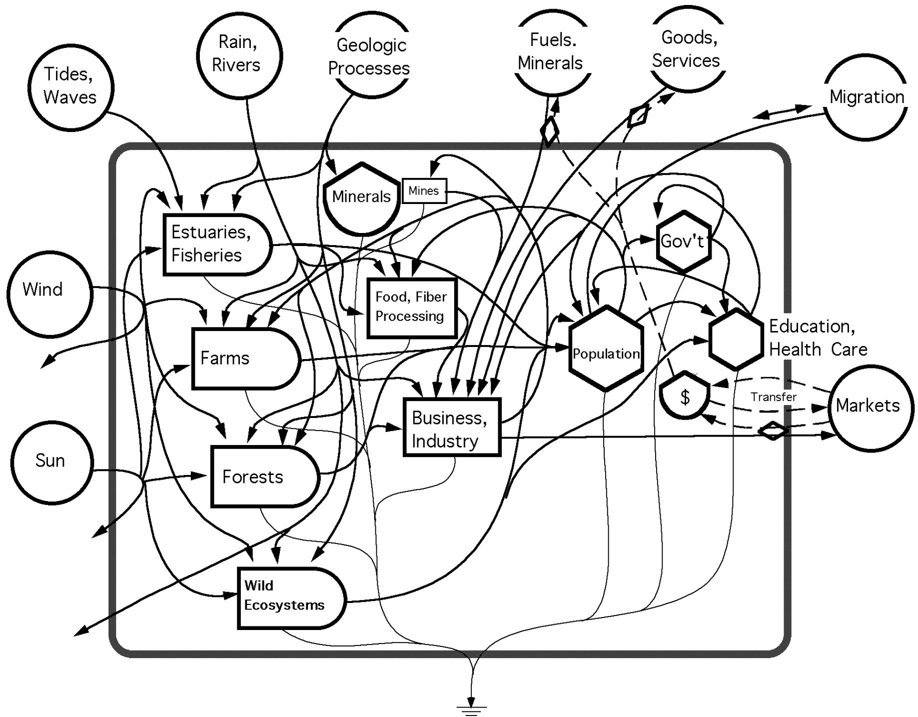

Figure 7. National emergy values are based on calculations of flows and storages in the systems diagram.

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.

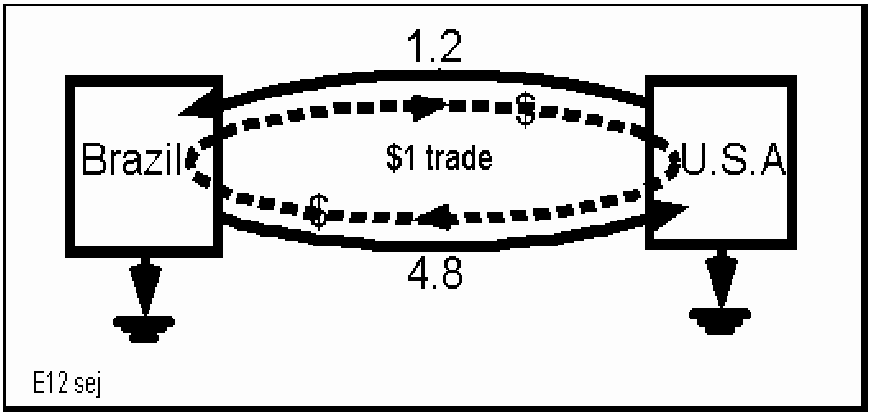

Figure 7 is a trade example which shows how emergy calculations can be used.

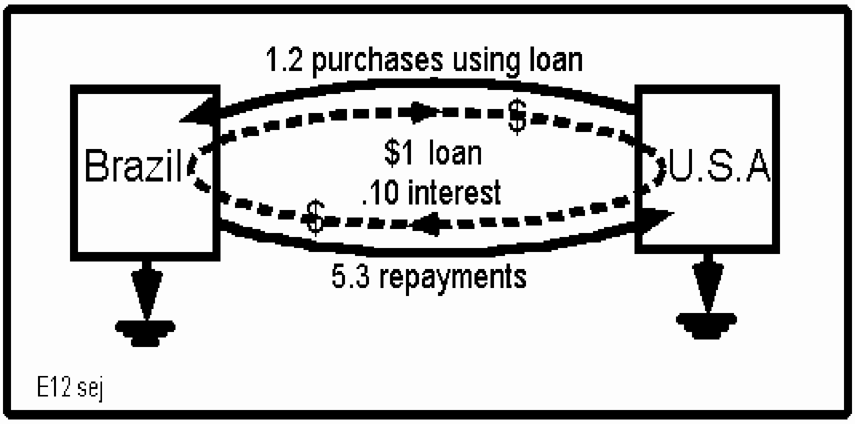

Figure 7. In an even dollar trade the USA can buy 4.8 E12 sej from Brazil; whereas Brazil can only buy 1.2 E12 sej from the USA.

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.

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Discussion

H.T. Odum and E.C. Odum, the prosperous way down

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> *For six billion people deeply indoctrinated in the ethics of growth, a turndown and descent of civilization is unthinkable. That this descent could be prosperous is so inconceivable that it is unmentionable.... Showing a good way down is a call for everyone to think ahead and plan.*
>
> –Odum and Odum (2001)

1. The carousel of progress

A political leader will never talk about descent, the Odums seem to suggest, because "for leaders to speak of a non-growth period is viewed as political suicide". The paradigm of growth is so deeply ingrained in our life style that we are unable to think any differently. Most of my high school and university education was affected by a very simple concept, namely that science would allow a continuous growth, removing all technological obstacles and solving all problems, for a prosperous life ahead. The concept of any "limit to growth", let alone of a "way down", never really appeared on my horizon until many years later. Certainly, the "limits to growth" paradigm, including the book by that name (Meadows et al., 1972), gained the attention of policy makers (without too much consensus, however). The original impact of that book has been enormously diluted by the incessant nay saying of all kind of experts who consistently berate the predictions of that model without bothering to verify to what extent its predictions are correct. However, the Odums move a step ahead. Their book, "The Prosperous Way Down" warns us that the "limits to growth" strategy is only a (good) transition step within an "up-and-down" cycle—The *"growth is progress" ethic of the industrially expanding world is being replaced now by "sustainability is good" for a world that is no longer growing much. Next, as people learn to live with descent, the ideal will be "down is better."* Such an ethic flies in the face of all our studies that have lead to the recent proliferation of papers on sustainability, and our hopes and dreams for a sustainable-for-ever steady-state. The Odums seem to suggest... Forget it, folks ... you'd better start thinking of a "pulsing paradigm".

2. A tale of growth and descent

The pulsing paradigm has always been in front of our eyes. Forest ecosystems never did anything different, with short pulsing cycles that we were able to see and understand. Deciduous trees bloom and grow in spring, make fruits and seeds (stored information) in summer, lose their leaves in autumn (for recycling by soil microorganisms), and seem to sleep and recover in winter-time, when available resources (solar energy) are less. On a longer time scale forests develop, grow, and then either senesce or are obliterated by very natural disturbances. Very similar resource-dependent patterns characterize all the other living species on Earth, including humans. Human societies grow and decline. The Roman Empire is now over and through its demise we may be able to recognize this trend. It took more than one thousand years for the whole cycle to run

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and about 300 years for the descent only. The longer pulsing "wave-length" makes it difficult for us to recognize the cycle of which we are part, while recognizing the shorter pulsing cycles of ecosystems. Tainter (1988) gives us so many examples of once-proud and enormous civilizations that remain only as stones under desert sands or the vegetation of jungles.

3. Adapting to environmental oscillations

If human societies are regulated by the same principles as other ecosystems and species on Earth, then it would not be a good policy "to paddle countercurrent", trying to force societies to grow when resources are scarce or to descend when resources are abundant. Instead, it would be a good policy to recognize the descent ahead and begin managing for it to be prosperous instead of impecunious.

"Policies based on understanding could be the difference between a soft landing and a crash"—this is, in my opinion, the main message of this book. H.T. Odum and his wife and partner Betty Odum spent most of their life trying to understand the principles and the characteristics of this pulsing trend as well as of each step of the cycle. They recognized four main stages of the pulsing cycle—(1) growth on abundant available resources, with sharp increases in a system's population, structure, and assets, based on low-efficiency and high-competition; (2) climax and transition, when the system reaches the maximum size allowed by the available resources, increases efficiency, develops collaborative competition patterns, and prepares for descent by storing information; (3) descent, with adaptations to less resources available, a decrease in population and assets, an increase in recycling patterns, and a transmission of information in a way that minimizes losses; (4) low-energy restoration, with no-growth, consumption smaller than accumulation, and storage of resources for a new cycle ahead.

4. Where in the cycle is the present human society?

According to the Odums' analysis, developed human societies are in the climax and transition phase, facing descent, but they still behave according to growth attitudes inherited from centuries of growth. The book explains and emphasizes the scientific principles, which govern the cycle, so that societies may become able to shift to new, non-growth attitudes, by being aware of what's going to happen in the time ahead. However, "Make no mistake, this is not a proposal for less growth. It is recognition that general systems principles of energy, matter, and information are operating to force society into a different stage in a long-range cycle". The Authors give a picture of the problem first, review most published papers on the topic, list the general systems principles governing society's dynamics, then try to extract suggestions and plans for the prosperous way down ahead, consistent with the resource oscillations. The book is fascinating, but the solutions presented are not the most important part. They are sometimes very attractive, sometimes questionable. What is new in this book is, in my opinion, the "systems view", a set of general principles, a new-Thermodynamics framework. The reader is driven towards the search for solutions within a well-defined frame, never losing the thread of the resource–growth relationship.

5. A new thermodynamics

The whole of Odum's scientific work converged into the search for systems principles within natural dynamics and into their application to human society. This book is more than just a legacy. It is a plan, a blueprint for survival and, at the same time, it is the basis for a new Thermodynamics made up with a set of different performances, each one fitting a different stage of the oscillation. The following is a look at some of these principles.

5.1. Pulsing

Pulsing is the main feature of the new scientific principles that may provide guidance for the times ahead. "It appears to be a general principle that pulsing systems prevail in the long run, perhaps because they generate more productivity, empower, and performance than steady states or those that boom and bust . . . Operations that pulse transform more energy than those at steady state".

5.2. The maximum empower principle

Expressing resources in emergy and transformity terms permits a re-statement of Lotka's Maximum Power Principle (Lotka, 1922) into a more suitable Maximum Empower Principle, according to which the simultaneous maximization of empower (emergy throughput flows) at all system's levels is required for sustainability. Hierarchies develop within each system, with higher levels feeding back and controlling the lower levels. High-transformity flows interact with low-transformity ones for maximum empower output. These principles provide a framework through which apparently chaotic patterns can be described and their behavior understood. It follows that the maximization of the available resource basis to maintain prosperity requires different strategies in different stages of development: fast competition in times of growth, efficiency in times of climax, decrease of population and assets in times of descent, low-growth attitudes in times of restoration.

5.3. The emergy yield ratio

To extract emergy out of a process (mining, cropping, electricity conversion, etc.) some emergy must be invested. The ratio of the total emergy of the product to the emergy invested is the so-called emergy yield ratio (EYR) and measures the net emergy benefit that a source provides to the economy. Oil has an average EYR equal to 6 to 1, that results from the unpaid accumulation of environmental work over million years of oil-making. An economy benefits from using or importing high-EYR resources, because the return on investment is proportionally amplified. Fossil fuels show high but declining EYRs, because the more favourable storages were exploited long ago, and progressively less favourable ones are being exploited today. Renewable energy sources and nuclear energy presently show lower EYRs than fossil fuels. Furthermore, renewables (sun, wind, rain and deep heat) already have a role in nature's self organization processes, so that diverting them to support an economic process reduces their input to useful natural processes. In so doing they may not always provide a net gain, due to the decreased indirect contribution of the environment. Unless unexpected (and unlikely) high-EYR energy sources are found to replace the declining fossil fuels, lower EYRs will generate lower growth and eventually no-growth patterns.

5.4. The emergy ethics and equity of trade

Money is not real wealth, according to the Odums. Real wealth is food, minerals, fuels, fertile land, houses, information, arts, and so on, and can be measured in emergy units. Money measures our willingness-to-pay for real wealth and only pays for the labor of those who make this emergy available to us. We do not pay nature for making minerals or cycling water. When a developed country imports primary resources (e.g. minerals, fuels, forest products) from a less-developed country, their cost is low, because labor cost is generally low in countries exporting primary resources and resources may still be abundant and of high quality. Money is in turn used to purchase emergy in the form of manufactured goods from the developed country. Since money pays for labor and labor cost in developed countries is high, only a small amount of real wealth goes to the less-developed country in exchange for the primary resource. Therefore, the emergy exchange (real wealth received versus real wealth exported) is uneven. Benefits only go to the already-developed nations, which become day-by-day wealthier. The long term stability of the global system is affected by these uneven exchanges.

5.5. Information

Since accurate and high quality information (not to be confused with digital "information" chocking the media and internet) requires a huge emergy support to be created, copied, disseminated and maintained, future societies will need to invest a large share of their high-quality resources, with special attention to the availability of electricity (a favourite energy carrier for information storage and use) toward the goal of storing information. "Mature systems contain large concentrations of information. The more complex a system, the more parts and interactions it has and the more information it must store in order to operate .... In mature stages of primitive human societies information was accumulated in the genes of their population and in the wisdom of their elders' experience. Our present human economy at maturity has great stores of information in libraries, universities, educated people, complex technology, and computer networks".

Special care should be paid to sharing and transmitting information. Shared information (common beliefs and values) helps stabilize societies at national and international levels, which may be crucial in times of descent. Universities may play the important role of long-range thinking, preserving and transmitting information, and developing new concepts. This may be more important in the long run than developing short-run research for industry or emphasizing patents and profits. However, information cannot replace the biophysical activities of, for example, agriculture, industry, and commerce. Contrary to many predictions of a decade ago, economies using high levels of information, have not become independent of resources. Italy, for example, has fuelled its recent prosperity on Algerian natural gas (among other fuel imports) even as ancient Rome was dependant upon the grain energy from Egypt.

6. Getting ready

Can the descent ahead be avoided? "Instead of denial, it is time for people at all levels of society to plan for a better world .... Coming down doesn't mean going back to ways of the past. In general, descent means new ways". The Odums call for less-growth and for a no-growth attitude. They also call for task-forces working for the prosperous descent. New, smooth strategies are not easy since they require education and preparation, and involve many if not all of the aspects of our daily life: money, welfare, school, housing, transport, population dynamics, international trade, religion, peace and war. Are the scientific, economic and social communities ready to receive this legacy and start working on it? To be honest, I do not think they are. Books like "The Prosperous Way Down" may lead the way, but much more remains to be done. The "growth paradigm" is still the winning option at the global level. However, the first signs of increasing awareness of a turndown ahead, as well as, of the need for a transition to a lower-energy future encourage us towards an additional effort in teaching systems principles and researching, planning and testing new solutions and strategies. If the Odums' picture is correct, the descent will not find us unprepared.

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