SUSTAINABLE CITIES AS A PART OF A GLOBAL ECOLOGY
- A Conceptual Framework -

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Setting a Theoretical Foundation

A fundamental distinction in the nature of technologies--solar or otherwise--hinges on their ability to become components in what might be called industrial ecosystems. Much of this potential depends on their inherent capacity to be integrative with other technologies verges resource conserving in and of themselves. In ecological terms, the cycling of essential elements in the biosphere is an indicator of life's basic need for materials and its responsibility to ensure continual material flows. Energy conservation is essentially the result of highly efficient systems working together, rather than as disparate machines optimized for a single purpose. Largely because human processes are viewed as individual machines rather than as integrative systems, the dominant anthropocentric world view holds a distorted, one-sided perspective of metabolic activities. The resulting integrative paralysis threatens the capacity of the human species to sustain life as we know it.

Examples of how this thinking relates to the field of renewable energy, particularly to passive solar, are numerous, but are stymied by a lack of confidence to extend them far enough. It can be argued that solar displaces non-renewables and thus reduces the need to introduce material cycles into the biosphere such as CO2, but we rarely go so far as to admit that residential construction alone in the U.S. uses approximately 1 million acres of virgin forest every year[1] knowing that these trees are the critical absorbers of this same CO2. Moreover, by uprooting these trees, soil nutrient erosion occurs at the upper slope level. This natural plant system, which is the means of nutrient cycling through decomposition, would take many generations to reestablish. Simply replanting trees fails to give the soil the important detritus critical for biological activity and water retention. This is but one instance of the enormous ramifications resulting from an absence of cyclical thinking in human endeavors.

Strategies for water conservation, energy conservation, and material conservation are proposed without the faintest idea of their full impact on larger systems. For example, is it better to produce energy conserving appliances such as refrigerators or integrate the old clunker with water heating, or slow cooking of food, or drying clothes, or....? Is it more important to have a water conserving commode or cycle more water through a whole system creating at every nutrient exchange a potential new use in constantly evolving integrative efforts? Rather than optimize integrative potentials, stop gap measures are devised to conserve energy and materials that virtually eliminate the potential for integration.

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1. National Association of Homebuilders

LESSONS FROM NATURAL SYSTEMS

"...it may be said that the one way flow of energy, and the circulation of materials are the two great principals or 'laws' of general ecology, since these laws apply equally to all environments and all organisms including man."[2] So what are these principals or laws that could be models for human activities that have seemingly been disregarded? For example, a mature climax ecosystem offers an ideal model for efficient energy flow or community metabolism. The following list summarizes this condition relevant to energy based on renewable energy sources:

1) The number of individual roles (species) increases until relatively late in the climax period.
2) The number of individual roles (species) develops from linear chains to complex webs.
3) The total population (including all individual roles) supported per unit of energy increases.
4) The rate of flow of energy is a more important indicator in determining productivity than the amount present at any one place at any one time.[3]

The following list summarizes this condition relative to materials, and is based on renewable energy sources:

1) The rate of cycling of materials is a more important indicator in determining productivity than the amount present at any one place at any one time (i.e. the turnover time of material cycles increases).
2) Material cycles become more closed (i.e. in a mature system less materials are lost or wasted).
3) The role of waste products in the overall health of the system increases.[4]

The role of individual metabolic process (i.e. the argument again here is that these metabolic processes could be the human extension called machines, or any other humanly controlled transformation process):[5]

1) The capacity to live together becomes increasingly mutualistic.
2) Communities of metabolic processes progress from rapid growth to developing mechanisms for self regulation and feedback control.
3) Individual roles or occupations become increasingly specialized relative to fitting overall community sustainability.
4) Information regarding past events as they might influence the future increases within the system.
5) Quality and health of organisms (individually and as a whole) increases.[6]

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2. Odum, Eugene. Ecology. Holt, Rinehart, Winston, 1963, p. 38.
3. Odum, Eugene. Ecology: The Link Between The Natural & Social Sciences, Holt, Rinehart, Winston, 1975, p. 156.
4. Ibid.
5. Fisk, Pliny. "Metabolic Planning & Design", Northeast Sun, March/April 1989.
6. Ibid.

Human "Synthesphere" vs. the Naturally Evolved Biosphere

To believe that human systems and natural systems can become one and the same perhaps is misleading; after all, a healthy natural system without the exploitive component called mankind injected into it as an industrial animal has no net export. Thus primitive man as a scavenger became part of the system. Several differentiating characteristics develop:

1) All energy in this biosphere system was renewable.
2) The metabolism of living organisms is executed by multistep regenerative chemical reactions in an aqueous medium at ambient temperatures and pressures. (One can count innumerable processes that do not follow this condition even if one is not a technologist).
3) The biosphere as a whole is extremely efficient at recycling the elements essential to life that has evolved over millions of years.[7]

The mining of raw materials is one of the largest energy users in industrial society. The U.S. economy extracts more than 10 tons of "active" mass (excluding atmospheric oxygen and fresh water) per person per year from U.S. territory alone.[8] If one includes the processing and manufacturing components of these , materials it represents industrialized societies' largest energy user.[9] The annual accumulation of durables in U.S. society is only 6% of the total manufactured; in other words, 94% is converted into waste residuals almost as fast as it is extracted.[10] In biological terms this amount of waste would correspond to a young, immature population. However, there are some encouraging realizations that could reverse this trend.

<u>The Dawning of Industrial Ecology</u>

Benzene is a by-product of the petroleum industry with over 14 billion pounds produced each year in the U.S.. It is a highly toxic substance to humans: if 10,000 people are exposed to 1 ppm in one year, one in four will develop leukemia.[11] Its disposal became such an acute problem that in the course of scientific inquiries of what to do with it, a use was accidently discovered in a lab. The use was Styrofoam™, one of the best energy conserving insulators. The plastics industry, this nation's fastest growing industrial sector, generates mostly unuseful by-products, though acceptable uses are being discovered as the industry's waste disposal problems mount.[12]

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7. Ayres, Robert U. "Industrial Metabolism," <u>Technology & Environment,</u> National Academy of Sciences, Washington, D.C. 1989, pp. 23-49.
8. Ibid.
9. Chapman, D.F. <u>Eneray Policy,</u> March 1975.
10. Ayres, Robert U. "Industrial Metabolism," p. 26.
11. Berger, Melvin. <u>Hazardous Substances: A Reference,</u> Enslow Press, 1986, p. 31.
12. <u>Design News,</u> Cahners Publication, Des Plaines, IL, January 1991.

Flyash, a by-product of coal fired power plants, can be collected with reasonable efficiency using electrostatic precipitators. The problem has been the 50 million tons that need to be "disposed of" annually. Much of the flyash, however, is suitable for cement production, especially the fly ash resulting from the burning of high calcium coal. This fly ash, as shown later, can either partially or completely replace cement.

In most cases, however, there is no purposeful materials balance or input-output plan for energy or materials; most decisions are made for immediate economic reasons or under crisis conditions.[13]

Since final products result from a linking, or "necklacing" of processes, overall energy efficiency is determined by the arithmetic product of the conversion efficiencies at each stage; a logical direction is to shorten this necklace bringing forth the following results:

1) By clustering metabolic units, energy and materials are more trackable and therefore controllable, particularly in small business environments.
2) Miniaturization of processes can make them more adaptable to local conditions.
3) Each node or metabolite can in itself be regenerative (i.e. use sunlight to produce more stuff than had originally had in mineral or raw material form through photosynthesis).
4) Combined nodes working as a whole system within an ecological context can become fractals that can borrow information from similar biological zones throughout the world.

EXAMPLE OF METABOLICALLY DESIGNED REGENERATIVE SYSTEMS

Several domestic and foreign examples of individual businesses or whole communities have purposely designed solar-based systems which enables them to become more productive at each metabolic point. Below is a food related example and a construction material example. The first is an organic farming kibbutz in Israel, Sdeh Eliyahu. In this setting, each metabolic point in an integrated organic farming community became not only necessary for the next to operate due to the need for the others' by-product material, but each was regenerative enough to become a lucrative business in itself. For instance, the compost needed for the organic gardens was used internally and sold; the insectuary produced benign insects for crops and was the largest of its kind in the Middle East with a global sales network; the organic food was of such high quality that it was exported to Europe for top price, as was the milk from the cows that produced the manure which provided one of the essential ingredients for the compost.

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13. Fisk, Pliny, "Multi-Level Production of Low Cost Community Produced Passive Solar Systems in Crystal City, Texas," American Solar Energy Society Proceedings, 1979.

Other food related examples in the U.S. are becoming more well known, such as bioshelters in the fish and protein supplement industry. Unisyn of Hawaii specializes in the production of spirulina protein and consults on integrated material and renewable energy systems.[14] Some small business examples are in the northeastern U.S., where AquaFuture Inc. Inland Fisheries Systems in Montague, Massachusetts has created a break-even business within a 4,000 square foot module, and the Three Sisters Farm and Nursery in Pennsylvania has successfully integrated food production with a restaurant and nursery.[15] Interestingly, we are unaware of whole community efforts in the U.S. comparable to those in Israel and China.

There are a few examples of regenerative mineral based material systems that bring about net gain during the process of manufacturing. One in particular, termed "accretion" by its developer, Wolf Hilbertz, collects calcium carbonate on a cathode under sea water to create a variety of shell structures with an average strength comparable to high grade concrete. The differences between accretion and concrete production processes are many and significant. Not only does the production of concrete account for 6% of the CO2 , thus making it a major contributor to global warming, it is also tremendously energy and water intensive. Accretion utilizes only 1/4 to 1/9 the energy as concrete but actually absorbs carbon permanently (unlike growing trees). The accretion process is regenerative in still another way in that one of its by-products is hydrogen which can be collected and used as fuel, and thereby dovetail nicely into what many predict to be the hydrogen economy of the future. There are other examples in the manufacturing field that this author knows of that work in similar ways, such as Sanford Ovshensky's solar photovoltaic manufacturing facility run by photovoltaics, but none is as striking an example as the work done by Hilbertz.[16]

INFORMATION BASE FOR METABOLIC SYSTEMS DESIGN

Input-output data needed to design integrated systems for biological or material systems is difficult to obtain. The integration of businesses is difficult as the data focuses on final products and possibly by-products, but rarely an itemization of input requirements. Even with these shortcomings, approximately 12 states publish provincial and regional waste exchanges. For example, California publishes a bi-annual catalogue that matches waste generators with waste buyers, and, as a result, has redirected about half a million tons of hazardous waste that otherwise would have gone to landfills.[17]

At the town or city scale, solar operated material cycling is virtually non-existent except through biological activity of microbes in large scale composting facilities, which are noticeably absent from most urban landscapes. Efforts combining the inorganic with the organic and are solar operated can be found in village development projects in Third

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14. Unisyn. 1203 East Street, Tacoma, WA.
15. Schuller, Phil. "The Bioshelter: Energy Efficiency in Food Production", Pennsylvania Energy, December 1988.
16. Wolf Hilbertz, President, Marine Sciences Laboratory, 252 Kenrick, Newton, Ma
17. "Strategies for Manufacturing", Scientific American, September 1989, p. 151.

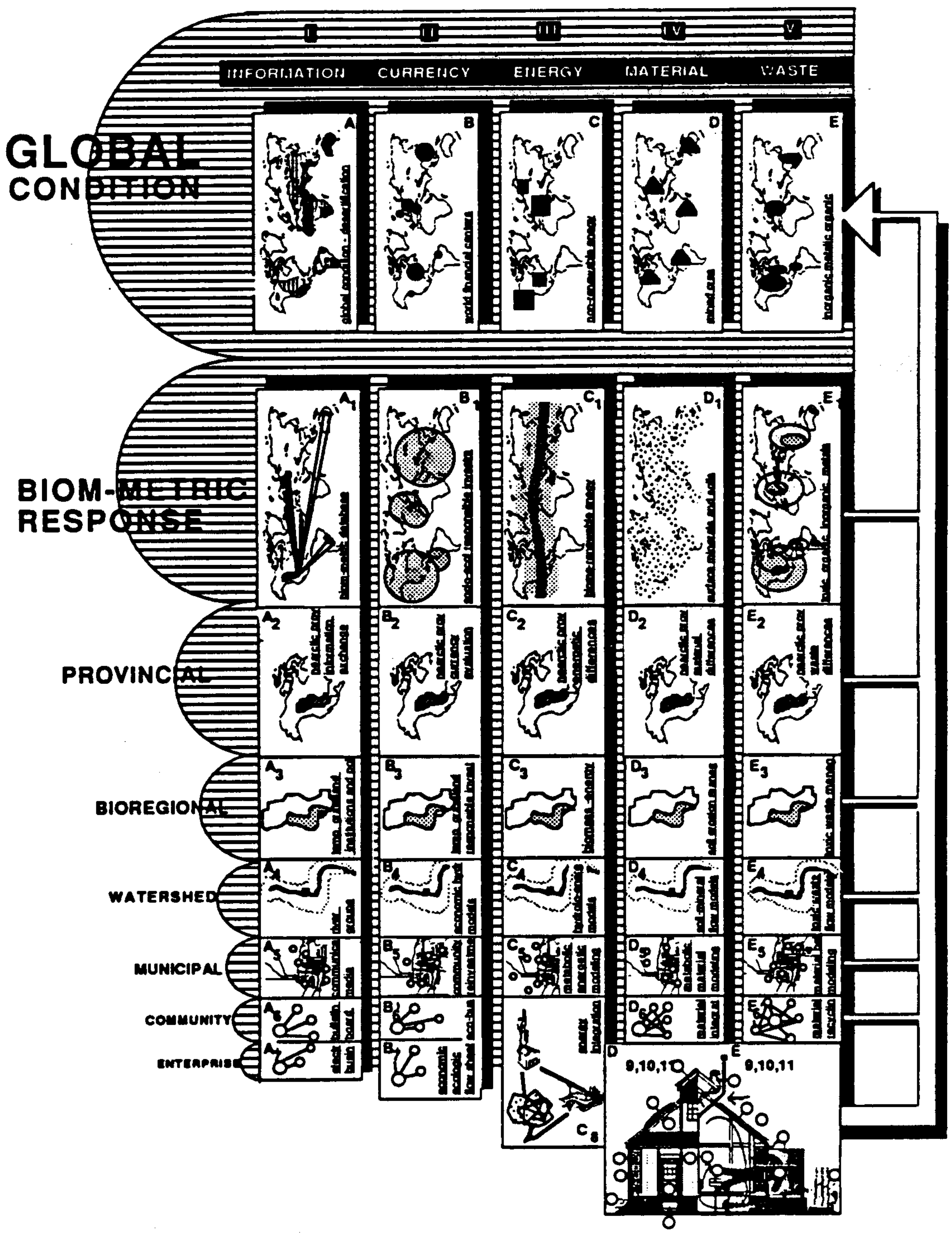
World countries. Thus, there is an enormous gap between the First and Third Worlds, with working examples of what can be done under relatively simple conditions in the latter, and a virtual void of examples in the former which is in desperate need of a new approach to infrastructure development.

INTEGRATION THROUGH BIOM-METRIC INFORMATION, PLANNING AND METABOLIC DESIGN

The biome system was originally developed for purposes of preserving plant and animal species according to whether or not these plants represented all global ecological zones. In developing the system, patterns of noticeable repetitions emerged, i.e. one ecological association being represented in different continents, termed "provinces" by biogeographers. This meant that if one associated their local condition to its biome, a pattern would develop of similar conditions worldwide. As one collected information on a variety of technologies associated with different local materials and energy flows directed towards human life support, i.e. food, potable water, renewable energy, waste treatment, building materials, one would be able to borrow technologies and practices developed under similar or identical ecological conditions. Over the years, we have found that large database sources covering, for example, renewable energy, could be physically located according to biome and used as a basis for networking information. We use the resulting information points as the basis for networking concerning any particular job we undertake and develop regional tool kits that in a sense are biom-metric tool kits.

Biome planning and metabolic design is also a process of both admitting to and working within a global perspective of trends, such as desertification. Once immersed in these trends, one can design artifacts in an energetic and material sense and help correct wrong trends induced by mankind and make this a part of a region's metabolism at the local level. In other words, the artifact is looked at as if it were a nodal process in a series of regional processes, all presumably linked together. The Biom-metric database is one tool that identifies methods that help nurture linkages with regional resources and, thus, the regional metabolism.

The chart below initially covers global problems in the areas of concentrated information, wealth, energy (fossil fuels and nuclear), mined materials, and large scale point source waste contamination, and translates these trends which are at the heart of global destruction into a new development vernacular. This new vernacular deals with **information** deriving from the biom-metric™ approach of similar life zones which is used as an information sieve. In order for human systems to properly relate to nature, a reorientation of priorities must occur. **Currency** is now decentralized through a number of new creative financing tools which in the U.S. is best represented through the Community Reinvestment Act which requires banks to invest a percentage of their loan funds into the communities in which they are located. **Energy** is now decentralized in the form of renewable energy that is dispersed and available to whomever can make use of its available level of concentration. Similarly, **material** knowledge is now transferred to building systems using the capacity inherent within regions. Some striking examples are described in the second part of this paper both of which are derived from the metabolic processes of industrialization or highly dispersed raw materials from natural sources. **Waste** is now considered only from a total materials balance context - thus bringing by-product recovery into a total ecological systems approach. The procedure should gradually develop into an accounting at various design stages, ideally making each building component a fractal or metabolite representation of how to design or, at least, an option of how to design within regional parameters. The design represents various increasingly larger scales of understanding up to the point of the global biome. Energy and resource conservation results from integration at the regional and global levels. In a sense we try to mimic nature and say "no such thing as waste can exist" through the use of metabolic planning.

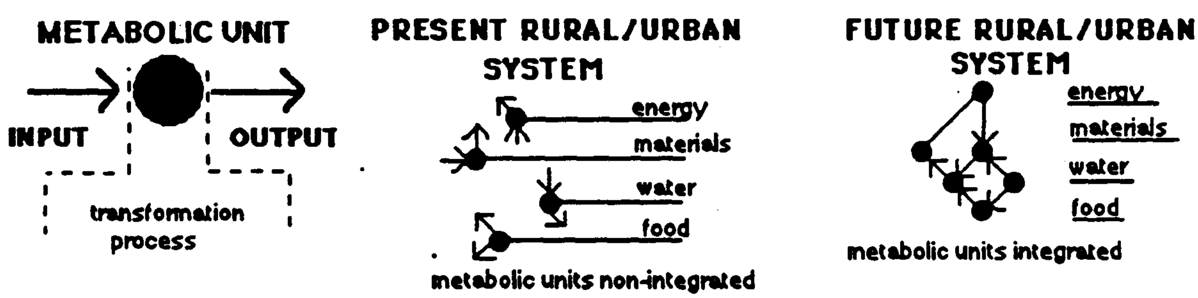


Metabolic Planning and Design

Where to start?

There are naturally many different starting points in order for sustainability to occur at any significant scale. For example, "Healthy Building" could become the precursor of the kind of value based, healthy economy desperately needed to redirect our towns, cities, and regions toward a more sane and sustainable future. By supporting and actively promoting these kinds of businesses, we go beyond health in our living environments and delve into how our towns and cities relate to their immediate regions. Healthy businesses, for example, related to the home building market involve the use of natural building materials, reuse of valuable organic and other "waste" materials, production of clean air and high quality water in our developments and communities, growth of non-chemically treated food hand-in-hand with native plant low energy and water landscapes, and, last but not least, the application of conservation and renewable energy technologies that take a region's total resource base into account in a multitude of overlapping scales.

I believe we are beginning to witness the symbiotic relationship between man and nature that builds not only a clean environment but, just as important, a healthy economy. Healthy businesses can be looked at, in essence, as the links that convert a region's raw materials into useful products. They can be looked at as transformation points or what I like to refer to as metabolic units that have an input, a conversion process, and an output which in many ways begin to mimic healthy natural systems, especially when they are continually linked in chains so that the input required by one process is actually derived as the output (waste?) of another. In this way, the metabolic planning and design process not only prepares raw resources for human requirements, but also prepares the by-products from our own metabolic processes for use in the natural world.



In order to think more clearly about the many levels of how this new approach to community economics could place the designer/developer in a key role to link us back to the way a healthy world must actually work, let me cite a few examples from many that directly relate to our own professions.

Examples

The first example is a materials related scenario. As you will see, the example that follows will grow out of the series of metabolic units described and directly connect to a solar-based example.

Sulphur dioxide (SO2) is perhaps one of the most serious environmental health hazards facing modern society, and results primarily from burning high sulphur coal and other hydrocarbons producing acid rain. Sulphur, as we all know, can be collected out the precipitator stack of a coal plant. So far the justification for such procedures has been based almost exclusively on environmental rationale, not on the basis of metabolic unit economics (except by the Japanese). It happens that sulphur is not only a useful chemical in many industrial processes but also is proven to be quite useful in a number of applications in the building industry. When used with gypsum, sulphur becomes almost totally fireproof. Structurally, sulphur concrete is able to achieve a compressive strength of over 5000 psi, and an adhesive strength in the area of 30,000 psi. Additionally, sulphur can be sprayed for structural surface concrete applications or shells, foamed to form a reasonable insulation, and used as a natural pesticide to retard home insect infestation. In many areas of the world, sulphur is less expensive than concrete; it is also the 14th most available element in the world.

A sister material also derived from coal fired power plants is fly ash. Fly ash derived from a high calcium coal or, when mixed with the lime slag after it has been used in the sulphur precipitating process, produces a concrete with compression strengths tested to exceed 12,000 psi. Both sulphur and fly ash require a fraction of the energy needed to produce portland cement. Not only has the Center successfully used both sulphur and fly ash in building projects, but we are presently developing a method to foam fly ash using organic, renewable foams to produce a lightweight porous concrete. We are particularly interested in applying this technique for use as a porous paving to increase groundwater replenishment, the absence of which presents a serious run-off condition in many parts of the U.S..

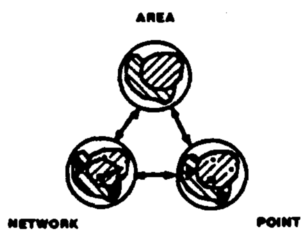
As we become more familiar with the processes behind each of these metabolic units due to their plethora of interconnection possibilities, we realize certain additional benefits from our interlinking and optimizing of regional resources. And, as we become more attuned to this way of thinking, we realize particular special attributes at the levels of community and regional economics at each level of integration.

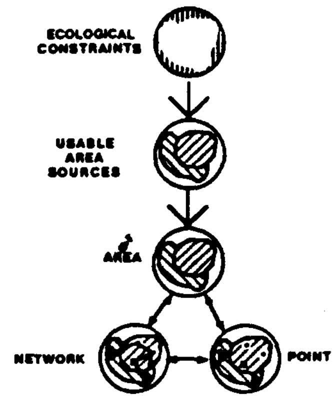
In Texas, for example, it happens that one of our major coal veins lies below other valuable resources, including one of particular interest, zeolite. Among traditional uses, zeolite was used by some North American Indians in their sweat lodges as a remarkable heat storage material. Upon close examination, one realizes that zeolite's high heat storage capacity is based on its high absorption capacity for moisture and its ability to duplicate what is now referred to as the "hot potato effect." This describes a reaction in which moisture within a medium is unable to circulate due to convection, thus extending its heat retention capacity.

Perhaps an equally important attribute of zeolite is that it releases moisture at relatively low working temperatures (200-400 deg F). In our part of the country-- the southwest --there is a high demand for refrigeration for many uses, particularly in the agricultural sector. Zeolite has been shown over the years to be a simple solar-based replacement for the absorption process within the refrigeration cycle and can produce sub-freezing temperatures when the medium goes through its absorption cycle in a closed loop system after being regenerated during the day using solar radiation. This use of zeolite introduces alternative refrigerants which may be a promising substitute for freon, which is directly linked to the depletion of the ozone layer.

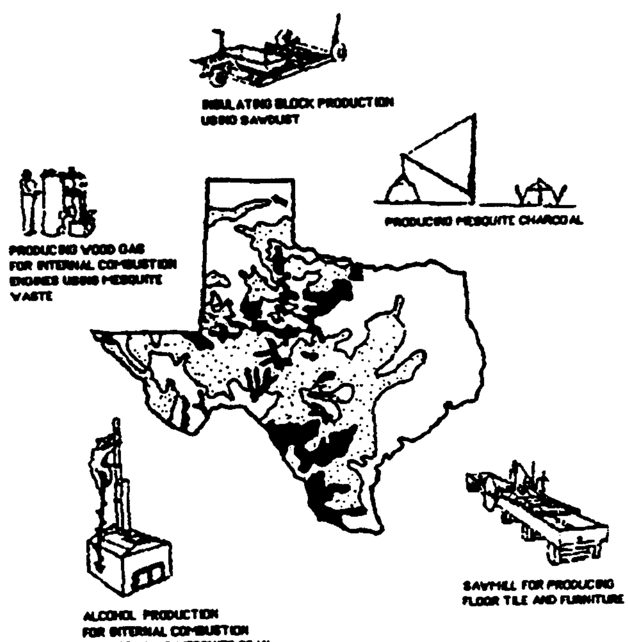
My fascination is not only with any of these technologies in themselves, but rather with their synergistic potential to develop an ecologically-based regional economy, and with reversing a mindset that focuses on the negative aspects of economic and environmental problems instead of on their potentials. With this in mind, our office in Austin, Texas is gradually bringing together the expertise to offer regional economic development services based on the simple principles of metabolic planning and design. We are even developing some simple terminology, often borrowing from a multitude of disciplines, to guide our thinking. We have taken the principles of ecological land planning and, rather than concentrating our efforts purely on "no touch" conservation policies, are instead looking at the environment as a matrix of economic potentials of many types in combination with sound environmental principles. We refer to the first step of this effort as our **Regional Working Atlas Series**™ which identifies a series of resources that connect directly with the principal life support needs of the region's population and environment.

This mapping process results in identifying **area resources** that, in effect, are the basis for our **point resources** or metabolic units. The point resources (businesses, industries, research institutions, etc.) that represent applied use of a region's area resources are highlighted and supported through our development plan. We then go through a process in regional economics called **network analysis** in which the inputs and outputs of these metabolic units are studied to determine a series of issues, such as their present and potential impact on human needs (the regional marketplace).



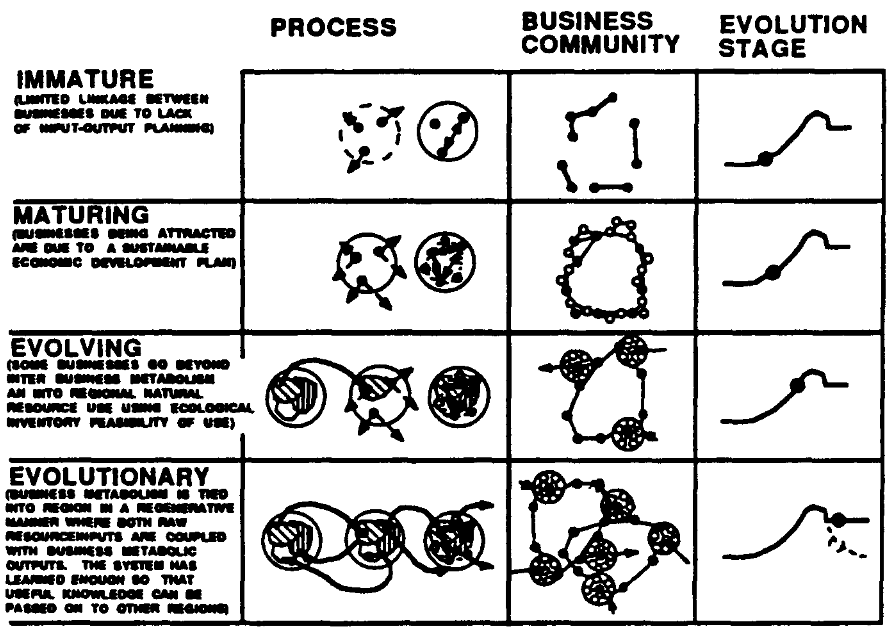


The important conceptual breakthrough here is to realize that spatial representation of life support resources, since they are spatially inventoried, can become a direct part of the land planning process. Thus technology is mapped which, in essence, maps economic development.



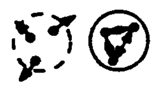
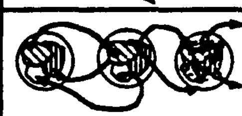
At one level, one often finds the existing **inputs and outputs** among and between regional enterprises unorganized, providing an opportunity for better integration. At another level, we find certain obvious gaps that can be filled by introducing another industry or business to better connect the inputs and outputs of local businesses. This linking process relies on what we refer to as **gap industries** or **gap businesses.** And, at yet another level, we at times discover an absence of knowledge related to a high potential industrial/commercial enterprise that could exist due to demand and the existence of an available natural resource that has not been tapped. Due to the high multiplier effect resulting from the use of such a resource, potentially producing many secondary and tertiary business potentials within the region, we refer to this effort as the development of **trigger industries**. The chart below summarizes some of these relationships.

SUMMARY OF CONDITIONS IN THE EVOLUTION OF SUSTAINABLE REGIONS



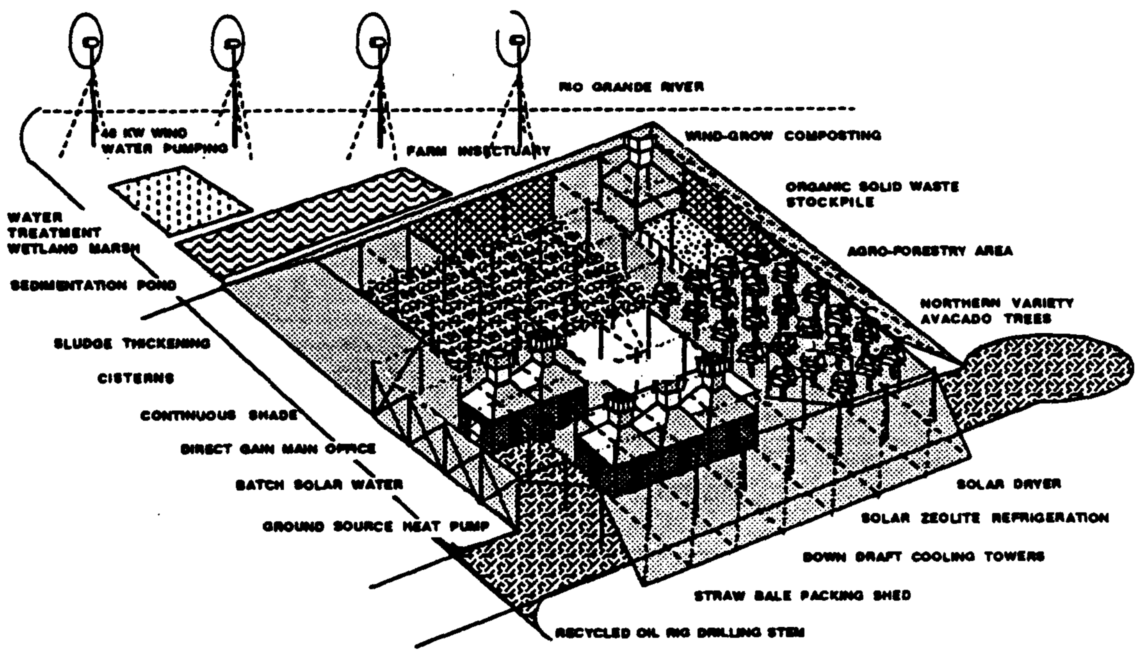
As I have mentioned, there are many other examples that we could choose from; the possibilities are endless even within the materials sector. The fact that in Texas the Center is now building structures out of 50-80% straw left over as chaff from graineries-- a "waste" material --is further evidence of the ability to spawn new economic outlets, in this instance in the agricultural sector. Or the fact that we must look with equal creativity at our wastewater treatment processes as having economic development potential for certain crops, biomass production, or for use in our native plant landscapes. As principal architects, engineers, and planners of the Laredo Blueprint Farm in conjunction with the Texas Department of Agriculture, we are introducing many of these examples as demonstration components. Shown below are the accompanying planning stages and methods appropriate to facilitate the evolution described in the previous diagram to take place.

BUSINESS ECOSYSTEM PLANNING STAGES

PROCEDURE	METHOD	CONCEPTUAL FORM
1 BUSINESS NECKLACING	INPUT OUTPUT ANALYSIS	
2 GAP NECKLACING	INPUT OUTPUT BY-PRODUCT ANALYSIS	
3 TRIGGER BUSINESS DEVELOPMENT	NEEDS ASSESSMENT CAPABILITYANALYSIS REGIONAL ANALYSIS	
4 INTEGRATED REGIONAL SYSTEMS	ECONOMIC / ENERGETIC SYSTEMS ANALYSIS	

Finally, it is important to note that when properly incorporated into a sustainable city program, such as the Center is currently engaged with the City of Austin through a grant from the Urban Consortium in Washington, D.C., we must treat the many options available to both the public and private sector as a continually building treasure chest. This means that material is presented in an interactive format in which creativity is spawned by a vocabulary of infinite options based on many new combinations. This, in essence, is the same open system that nature itself is accustomed to operating with; not a dogmatic set of rules, but instead performances that must be met by options that develop almost daily due to the rich hybridization of ingredients.

One of the most exciting potentials for this new type of development is in the form of a new breed of industrial parks on the **urban fringe**, where as in the zone between the the forest and the field maximum information and material flows, where life is the richest. These zones could become what we like to call the **city gates** of the future. We look at our work in Laredo, Texas on the Laredo Demonstration Farm as one of these gates due to its connectivity of three crucial elements to the life of any city: the processing of organic wastes into organic fertilizer; the treating of water to rid it of toxic substances using high plants; and the production of healthy organic food. A diagram of this farm is shown below.



So we must go beyond pristine, hermetically sealed self-sufficient environments to a new level of ecological land planning and design in which there is a true partnership between people and nature, not simply a naive mimicking of nature itself. Our mapping procedures now must become a basis for regional economic development as the first step in breaking down the artificial boundary between technology and nature that we have managed to create. It may be that the physical land planning efforts or even the individual homes that we have on our drawing boards today could be the keys to demonstrating how good planning and design coupled with creative economic development can foster an entrepreneurial spirit in keeping with ecological awareness.