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## ECOLOGICAL ACCOUNTS: Prerequisite to Planning for Sustainability

Richard L. Meier

*This article describes a three-part model for comprehensive ecological planning for urban communities. It reviews the history of accounting, from the measurement of material wealth to the measurement of complex physical systems characterized by multiple energy flows. Models of sustainable ecosystems, Meier argues, must account for the flow of information and the generation (or loss) of new knowledge within and between communities, which challenges the conservative principles of monetary and energy-based forms of accounting. Sustainable outcomes, Meier argues, should also be measured in terms of increasing numbers of voluntary transactions, qualitative redistribution of human time and attention, and overall improvements in the quality of life.*

The term *environmental sustainability* is rarely defined in a rigorous way. A working program for energy conservation, intensive recycling or water reuse encourages community leaders to make claims of sustainability. However, the concept itself goes beyond prospects for survival over the long term—it presupposes that the quality of life would not be destroyed in any significant way. *Sustainable development* should assume that better states of existence are being found, so that it is possible to make improvements without increasing risk to the system as a whole.

To assure sustainability over the long run, ecological accounts are needed to record the changes occurring in local communities. Ideally, the accounts employed should: (1) comprehend all major populations and resource flows prerequisite to community life, (2) take into account the historical precedents and the inertia inherent in present trends, and (3) aggregate into indexes of human welfare that enable the stabilization of flows *among* communities. In addition, new accounts must offer unambiguous ways of accounting for the two percent or so new products and services that appear each year. Innovations must be incorporated in the measurement of intake, production, and stock on hand for renewability of the environment, and the estimation of *sustained yield*, a concept important in forestry, agriculture and hydrology.

Philosophers employ a form of accounts in concept when proposing the components of human welfare and assessing the quality of a lifestyle. Policymakers need similar accounts when preparing cost/benefit evaluations for alternative paths into the future. As new forms of accounts evolve and guide data collection, they may displace many measures now based upon market price.

Ecological planning accounts for more factors than have traditionally been measured by philosophers and economic planners. To take advantage of the most precise and comprehensive scientific measurables, Boulding (1978) superimposed a new triad: *energy, information and materials*, on the economist's classic model of *land, labor and capital*. The importance of these extra factors became evident when the urban ecologists of the world met for the first time in 1987. The locale was Beijing, the participants numbered in the hundreds, the language of discourse was English, and all the published schools of thought were represented. Participants discovered that each school had, in the pressure to specialize, left categories of actors and key flows out of serious consideration. They then came to consensus on a simple model that seemed to fit even the most complex communities by elaborating on Boulding's trifurcation in significant ways. They arrived at an organized checklist that could be represented as a mnemonic like a Mendeleev Table in chemistry, the Grand Unified Theory for particle physics, and the Human Genome in biology.

The complete accounting challenge—populations to count and inputs/outputs to measure—is laid out graphically in the following Figures. Figure 1, *Ecostructure*, depicts the range of actors constituting a modern urban community. Figure 2 identifies the significant flow-through of resources into and out of these communities. Resources are “processed” in the form of human interactions that are a significant measure of sustainable systems. Figure 3 depicts the life cycle of individual elements: people, organisms, machines, software, etc., as these relate to the need for and production of resources over time.

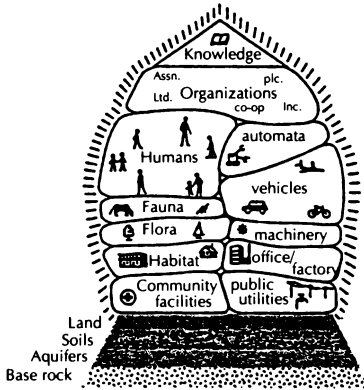
This breakthrough should have diffused rapidly throughout the field of human ecology all around the world. Unfortunately the Congress Proceedings lie unprocessed in the archives of the Chinese Academy of Sciences, due to the perturbations caused by events in Tiananmen Square shortly thereafter.

### **Evolution of Accounts: Wealth and Energy**

Historically, the first true accounts measured flows into and out of a warehouse or a treasury. They are ascribed to the Venetians as a private effort to maintain control of commerce at their various trading

Figure 1

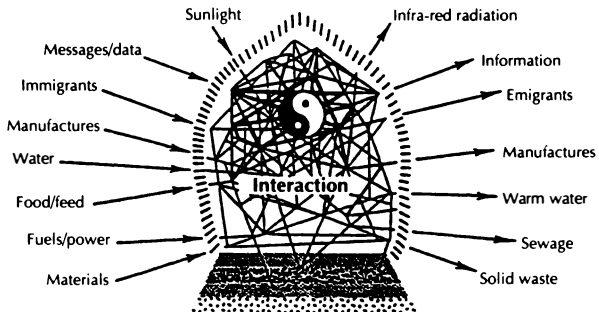
Ecostructure



Populations of actors comprising the modern urban community.

Figure 2

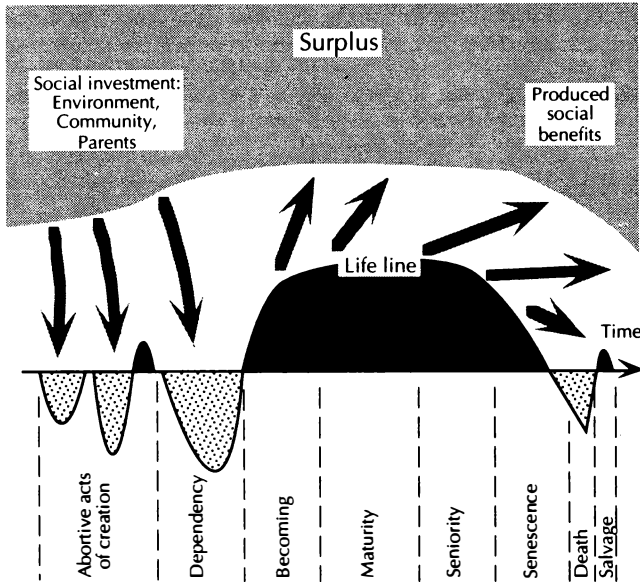
Resource Flows



Transactions between actors processing inputs and outputs are the life of a community. The *yin-yang* icon represents a harmonizing institution insisted upon by Asians that goes above and beyond markets.

Figure 3

The Basic Life Cycle



Lifetime use of resources for individual people, organisms, machines, software, etc., is strongly non-linear, except for the period of maturity. Areas below the time line represent investments of scarce resources; those above the time line represent production of resources.

posts, perhaps around the twelfth century. With these accounts, the Venetians tried to measure the profit from enterprise. They had a counting house for gold, silver, base currencies, obligations to pay, and certifications of cargo, as well as standardized containers in the warehouses. Thus they were able to aggregate the values of what was owned into a measure of wealth attributable to the respective merchant households.

For several centuries an improving ability to measure commercial values kept the Venetians ahead of their Mediterranean competition. Over time their techniques were imitated and widely diffused. On the

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other side of the world, where commerce had independently reached the same levels of intricacy, the Japanese merchants of Edo and Osaka worked out their own version of accounting. It is one of the ironies of world history that the European formulation became a foundation for the livelihood of the outward-looking urban community, creating its *bourgeois* stratum, whereas the Japanese and their Chinese trading partners eventually were ordered by imperial edict to break off contact with the outside, thus cutting short their advances in the management of commerce.

Free trading communities had an open culture which made it possible for the natural sciences to progress within them. Navigational instruments made possible the measurement of distance, whether at sea or on land; these were later combined with the chronometer. The transformations of astrology, a practice shared with the East, into astronomy, bolstered the measurement of space among European nations, creating another kind of accounting that permitted the founding of transoceanic empires that transcended the parallel efforts of the Chinese vanguard. By about 1500, when the two systems of exploration collided, the "space technology" of the Mediterranean proved more effective.

This background sets the stage for subsequent accounts of energy. Invention of the thermometer to measure the degree of heat, and the calorimeter to measure quantity, were prerequisites for quantification of energy. Energy is a highly elusive phenomenon, as compared to space and time. Since we cannot always experience it directly, psychological judgments, such as are applied to sound and light, are ineffectual. It took hundreds of experimental advances through the whole of the nineteenth century to master the measurement of heat and heat flow, mechanical energy, rotational energy, electric power, sound and the energy in electromagnetic vibrations. Conversion constants for transforming one into another were calculated with ever-improving accuracy during this time.

Economists, who borrowed marginal analysis from the mathematical physics of the day, should have become involved in energy accounting. However, their central interest in pricing through the market blinded them to its huge potential for assessing other forms of efficiency. We are indebted to Martinez-Alier (1990) for bringing to light the work of intellectual scientists and engineers who circulated on the fringes of political economy circles in Vienna, the salons of Paris, the lecture halls of Berlin and the libraries of London. Very early they interpreted the socio-political and economic meaning of the formulation of the laws of thermodynamics and their implications for a sus-

tainable society. Within a decade or so after those “iron laws” had been formulated, they were roundly criticized by the lions of that period—Karl Marx, Max Weber and L. Walras, particularly—for what are now accepted to be wrong reasons. Accounting with energy units was promptly forgotten until the latter years of Nicolas Georgescu-Roegen (1976), when the “energy crisis” renewed attention. Wasteful mispricing, which deflected attention from its anticipatable scarcity before the life cycle of existing infrastructure had run out, was attributed to market imperfection and erroneous regulation, and not to poor science and imperfect accounts within the dominant paradigm.

### **Beyond the Laws of Conservation: The Production of New Knowledge**

Accounts provide a solid foundation for building an imposing superstructure of knowledge, as well as the economic organization. History has shown us that measurement of a phenomenon that is not ephemeral (e.g., utility, solidarity, etc.), but conserved, has very powerful consequences. Distance between two points on Earth is invariant, so through the theorems of geometry, space is conserved. Wealth for the Venetians had to be conserved or the Company would fail, so accounting by the gold standard was invoked to save it.

This principle of conservation became the basis for energy accounting—what entered into a closed system eventually came out. If it did not, it must reside in the “exchequer” as a stock on hand, often in the form of a changed state of matter. All these changes in matter, whether from solid to liquid or liquid to gas, involved a constant quantity per unit mass of a given substance. Each pure material gave reproducible results everywhere on Earth when manipulated in a standard way.

To make the design of chemical processes and products possible, tables have been constructed which provide measures of the amount of energy content, or “fuel value,” of known pure substances. These tables all refer back to standard conditions, set at 20 degrees Celsius, and a barometer reading of 760 mm of mercury (sea level average), so that minor corrections can be made for the temperature and elevation of a site.

Scientists have agreed upon names for the respective pure substances. With the advent of atomic theory they have invented increasingly complex images of how the component atoms are connected and arranged. In that imaging system, energy, in the form of heat, is the jostling of the atoms. At high temperatures the movements become so agitated that the weak connections between atoms begin

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breaking up and reforming, as in the case of melting and boiling. When conditions are very hot some tightly bound atoms break loose. We see flames, and new molecules are being formed from the fragments. The amount of energy, as measured by experiment, is proportional to quantities of products formed.

Theories based on these linear, additive, reproducible relationships work exceedingly well until the measurements reach error levels below a tenth of a percent. Demonstrating the universality of energy accounts was one of the greatest achievements of scientists in the nineteenth century.

The Second Law of Thermodynamics says that only a portion of every energy resource can be converted to doing useful work, and that amount is temperature-dependent. By useful work is meant such community activities as transport, including pumping of water; generation and distribution of electric power; production and recycling of metals, plastics and other materials, and their forming into artifacts; and production of fertilizers and chemicals for food production. This limitation led to an early concern for conserving fuels that possessed a high capacity for work, because until then it was observed that growth in demand for fuels had been closely associated with increases in welfare and quality of life.

The amount of electricity generated in Western societies doubled every decade this century and seems likely to continue growing. Meanwhile, developing countries endeavored to catch up with a demand that sometimes tripled every decade, almost always ahead of generating capacity. Projecting resource supply vs. demand suggests that the world will be energy-starved by the end of the 21st century, with the needs of at least half the world not yet met.

Most economists currently assume that new science will open up added supplies of energy, which explains their indifference to conservation. It is an assertion of faith, with no evidence being presented other than an extrapolation of long historical trends. For specialists in geology and forestry, drawing upon current data, this belief appears to be utterly nonsensical and improvident. Looking forward a generation (2020-2030), they see trends such as the reduction in useful reserves of petroleum and gas by more than half, coal by a third, forests by half, and arable soils by more than ten percent, while the urban population creating the demand increases by 70 to 80 percent. The energy resource specialists are frightened that the energy pinch could lead to massive deprivation, and tens to hundreds of millions of deaths from famine.



Both positions, however, are demonstrably wrong. They neglect the production of new knowledge (as illustrated in Figure 1) accumulating outside their disciplines as it affects energy use and supply practice. Specifically, *demand side management* involves the dissemination of the techniques of energy conservation acceptable to consumers and small contractors. Over the next quarter century another 50% of the projected energy demand can be reduced at costs lower than costs set by the current price of energy. (Thus the profit incentive works, and little regulation is needed.) If prices go higher, another 50% of the remaining energy demand can be reduced by known innovations with no felt loss in quality of life (Schipper, Howarth and Geller, 1990; Schipper and Meyers, 1992). The potentials for energy saving are as great in the developing world as in the highly industrialized countries, but will take longer to implement (Munasinghe, Kothari and Gopinath 1991).

Much energy waste can also cut through *supply side management*. Energy monopolies have been created by government (or allowed to form) to prevent duplication of infrastructure and achieve economies of scale. These monopolies must be regulated to prevent excess profits, but these rules are becoming archaic and inefficient as new technologies appear and offer alternatives not previously imagined by regulators. Reform, redesign, local competition, and re-regulation are needed to let in new energy sources from thermal solar facilities, windmill farms, geothermal wells, biofuels, photovoltaics, shared transmission, and marketing. The amounts to be gained vary greatly from state to state, but insiders estimate that those sources may eventually save between 20 and 30 percent of the current energy flow, and more in the form of maintenance and capital costs.

### **New Knowledge and Energy Savings in Urban Communities**

For the designer, retrofitter and manager of buildings and households, in industrialized countries at least, software can be purchased that incorporate standard tables of the energy-related properties of matter. More elaborate software models contain optimizing procedures which allow the designer to choose between saving money or saving energy. These simulations forecast energy consumption in a structure with an accuracy of between 10 and 20 percent about 90 percent of the time. Unusual behavior on the part of the building occupants usually explains deviations greater than that.

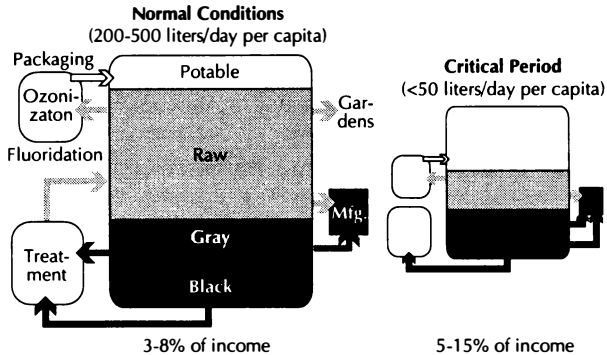
Urban consumers living in the most technically advanced cities presently use ten to thirty times as much energy for assuring comfort and convenience as is necessary. Through careful design, and atten-

tion to systematic waste, that level can be reduced to three- to five-fold, after measuring the energy flows for each activity sub-system, and considering alternatives. The magazine *Home Energy* appraises the innovations, reports on normal efficiency of appliances and ap-purtenances, reviews software, and describes strategies of implementation through retrofitting existing structures. Sophisticated designers have to go to the theory underlying the software; work out their own optimization, based upon the site and the services to be delivered to it; assess the impending scarcities and risks of the region; and incorporate the predictable modifications in behavior of users during the life cycle of the structure.

Another example of this new knowledge comes from urban transportation in developing countries. For the ordinary people in Asian and African cities there seems to be an evolutionary process in vehicle use. Pedestrians save time by buying bicycles, some of the cyclists move on to mopeds and scooters or to three-wheelers, and then graduate to baby taxis. Mini-buses and buses serve highly trafficked districts. None of these utilitarian vehicles contributes to prestige or serve as symbols of power, however, so they are discriminated against by higher-status lawmakers and civil servant regulators in charge of traffic and land subdivision. Time costs are the strongest determinants of *locations* in settlement space and the uses of *land*. All urban sites have occupants in need of connections with a network of streets and highways. Strict energy budgeting for urban life suggests that a high priority be given to bicycles, made available in many shapes and sizes. A sustainable, truly low-energy city design for the future has few niches for private cars. Optimal designs for circulation get us into *time* and *land* budgeting, which will be discussed shortly.

Sustainable use of water and water recycling constitutes another area where new knowledge can be applied to achieve energy savings. Chinese and Indian societies have independently evolved safe and economical treatments of sewage which remain taboo in America and Europe. "Fish farms" use sunlight to convert a sewage pond to an alga culture, introduce fish to eat the algae, and put waterfowl on the pond surface. The feared bacteria and viruses completely disappear in three to five days, while the carp and tilapia control the mosquito-borne diseases like malaria, and small amounts of sludge lock up the heavy metals. The aqueous effluent can then be used for gardening or rice culture. The much larger cities of the future must adjust their regional accounts to technology combinations such as that shown in Figure 4.

Figure 4

*Sustainable Water Supply*

A sustainable water supply should be sold at a variable price, depending upon scarcity and processing costs. Under normal conditions, water purchase should require no more than three to eight percent of gross income; to reflect its scarcity during critical periods, however, the price of water should rise significantly.

Pristine water coming from the mountains through reservoirs and deep wells should in ordinary times take care of day-to-day consumption. However, drought comes every three to thirty years. Then recycled water becomes important for survival at a decent level of living. Energy costs go up exponentially with the intensification of recycling of polluted waste streams, so at some point the costs become intolerable. Growing cities are forced to buy the rights to new supplies in the hinterland, sometimes even in neighboring watersheds. Water accounts must be fitted to the technologies for distribution and recycling.

### **Budgeting Time and Life and the Prospects for New Knowledge**

Another aspect of ecological accounts is the life-cycle of the individual person. The use of human time can be adapted to double entry bookkeeping, although this has seldom been applied outside the measurement of labor and capital-intensive manufactured products. A human lifetime is a kind of income; it is an aspect of living that is allocated to different needs and interests (Szalai 1973; Fox 1985). Part is

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taxed by society, which imposes obligatory duties (military service, obtaining licenses, voting, etc.), and another part by the community (elementary education, attending meetings, more licenses). Part is contracted out to employers to receive wages and salaries, and a much smaller part to non-profit non-governmental organizations (e.g., churches, cultural and political groups) to obtain desirable services (Boulding 1977). Quite a bit of time is invested in training, with the expectation that it will save time later (writing clear prose, practicing on a keyboard, computing) in participatory transactions. Some part of a lifetime is lost, however, in space/time friction such as commuting or queuing.

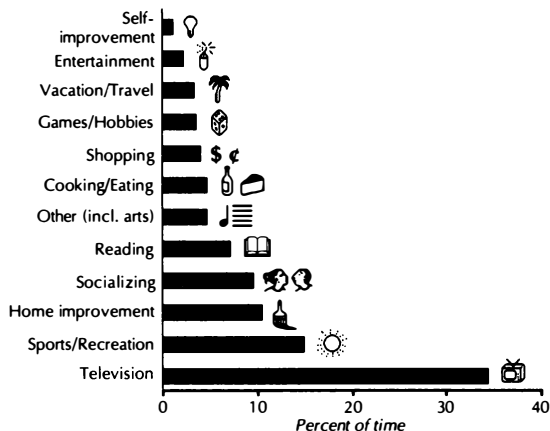
Sampling over segments of the population, days of the week, seasons, and the calendar year gives a representative picture for how a region or a society spends its time. Eric Miller (1991) reviewed 150 recent surveys and marketing reports based upon the uses of time left over from sleep, work, commuting and personal care in the United States and Japan. This disposable slice of time might be called "leisure," although so many appointments and obligations have been crammed into it that it no longer is spent in a leisurely fashion. Contrary to common belief, Americans work more hours per week (probably because work taken home in Japan is not called work, and the labor force participation of women is greater in the U.S.).

Figure 5 shows how Americans allocated their "free time" according to Miller. The trend in the United States is to schedule more "quality time" with family and close friends. Most often these moments are taken away from what was previously spent viewing television. Mass broadcasting is particularly vulnerable to substitution, since specialized forms of cable television are rapidly growing in popularity (home shopping, sports, drama, religion, games, etc.) from a small base.

There seems to be a strong tendency for literate, urban societies to converge in their allocation of time, if the breakdowns of interest to marketing professionals (as in Figure 5) are any indication. The poor have much less free time, because they spend so much of it "just waiting" for work, welfare or health service. Black mothers in the 30-40 year age range have the least leisure time of any population segment in America, because they are struggling to overcome one crisis after another. The quality of life seems to depend heavily upon both the amount of disposable time made available and the pattern in the uses of time.

Figure 5

*How Americans Spend Leisure Time*



Continuous surveys overcome bias due to weekly, seasonal and annual cycles. Television is now replaced by more active uses of time, as it had once displaced radio, “hanging out,” child watching, sleep and less valued time. Source: Leisure Trends Inc./Gallup Organization, as reported in the *San Francisco Chronicle*, Dec. 2, 1991.

Ecologically responsible designers connect past sequences with the present and a future that allows, even encourages, less consumption of scarce resources. Designers should introduce an increasing range of options (often time-saving shortcuts) appropriate to the human life cycle as the buildings or products age. Urban communities will be opening up these options increasingly over the next generation, and designers must take them into account. One promising device is to join a design-marketer-educator organization that sells “design/build/operate/train/transfer” competencies to the client.

**Transactions as the Currency for Ecological Accounts**

Patterns of human time allocation can be obtained relatively economically, but they do not contribute very much to planning and design beyond serving as an alternative to money values. Time can be saved in some aspect of life, such as transportation, and then simply distributed over the same categories as before, so that time saved in

car-pooling is spent on additional driving trips later in the day. Therefore, the ultimate allocations in the time budget after a major improvement in the experienced quality of life may be indistinguishable, when compared to that which came before.

One measurable increase, however, can be *the number of public transactions completed per unit time* (Meier, 1962,1968). Transactions, some of which are detailed in Figure 6, are the “atoms” of life

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**Figure 6**

*Characteristics of Transactions*

<p><b>Actors</b></p> <p>one/environment one/one one/many many/many (two organizations)</p>	<p><b>Exchange</b></p> <p><b>What?</b></p> <p>information location materials service help</p>	<p><b>Address</b></p> <p><b>Where?</b></p> <p>geo-code channel environs private public area</p>
<p><b>Calendar Date</b></p> <p><b>When?</b></p> <p>preceding what following what season clock time era</p>	<p><b>Process</b></p> <p><b>How?</b></p> <p>question/answer look/find here/there bid/offer etc.</p>	<p><b>Payoff</b></p> <p><b>Why?</b></p> <p>respect security love money learning</p>

Transactions are “atoms” of life in the community ecosystem. They are countable and classifiable with networks of computers.

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in the community ecosystem. Voluntary transactions in which both actors expect to increase mutual quality of life and personal happiness are win-win situations. But they also need to know the long-term outcomes of their transactions as well. Transactions that promote long-term sustainability of the urban community constitute win-win-win situations. Winning sequences can be learned, and repeated. Over time such transactions are the basis of interdependence, or *bonding*, between actors in a community. Familiarity with the built environment, client relationships, and friendships are created by repeated transactions.

In the computer age transactions can be sampled very easily, and the amount of *information* transfer in a community can be measured (Meier 1983). That capability leads to the expression of another entropy law affecting sustainability of communities. *The stocks and flows of information in an urban community must be conserved (or increased) over time, or else it will dissipate.* The stock of information, labeled "Knowledge" in Figure 1, is accumulated almost entirely by Organizations, especially those engaged in scientific and social research. The flow within and between communities, and the stock of knowledge that is available to all through telecommunications, are measurable in gross, physical terms and can be readily estimated in meaningful, non-redundant aggregates.

One of the great challenges in ecological accounting is to obtain measures of the number, distributions, and diversity of *transactions* per unit time. Such numbers would display a much more direct indication of changes in quality of life than income or social status. They combine economic, social, cultural, environmental, and political interests in a compatible and much less biased way than money accounts in cost/benefit analysis, even if the latter have been revised as suggested by Goodland *et al.* (1992) to meet the demands of environmental critics.

Transactional accounts can also be used to complete Boulding's triad of energy, information, and materials. Chemical elements, pure compounds, and standard commodities are easily followed through the records of transactions. What was a paper trail has become an electronic trace. Confusions arise in commerce, where mixtures are sold under brand names. However, for reasons of human safety, the compositions of various marketed products are obtainable when needed. If there is a threat to health (*e.g.*, air pollutants), or security (as in plutonium accounts), or looming scarcity (as with helium), it will be worthwhile to expend the effort to compile the stocks and flows.

Recycling of materials at increasing cost, depending upon the degree of purity required, will very much resemble the process for water shown in Figure 4. The irreducible, non-recyclable residues dispersed in water go into the soil or the ocean, but other materials will be incinerated and end up as traces in long-lived materials like ceramics, steel, concrete, or in sub-soil. All of these fates for once-useful materials are consistent with sustainability.

The flow of materials and information within and between communities, and the stock of knowledge that is available to all through

telecommunications, are measurable in gross, physical terms and can be readily estimated in meaningful, non-redundant aggregates.

### A Human Development Index

The graphical models outlined in Figures 1, 2, and 3 suggest a series of dimensions, out of which it is possible to establish twenty or thirty accounts required for sustainable development. These would reflect the vulnerability of a community in the present time, and suggest where and how much it must change in order to meet the threats to improving or sustaining a high quality of life.

A combined index of human development is possible. The United Nations Development Program (1993) has such an index for member countries. The Human Development Index (HDI) is calculated in a way that it could be independent of climate and type of government. It measures improvements in the abolition of inequity, poverty, unemployment and vulnerability to disaster, rather than ecological sustainability of urban communities, but its uses have come very close to what is proposed here for guiding community ecosystems into the future. The data presented by the UNDP provide evidence that, on the average, urban organizations induce greater health and more adequate nutrition; they also increase family planning, women's welfare, education, telephone use, newspaper reading, and other improvement measures consistent with the model above.

One subtle error of omission made by UNDP civil servants in the interpretation of their own data does relate to community ecosystems. Their tables show us that the surest way to improve the Human Development Index for a poor society would be to urbanize a greater share of the population. Cities seem to be "engines" that push alert, struggling peoples up to a decent level of existence. The competent, dedicated individuals in aid-giving agencies rarely think of voluntary migration to cities as enrollment in "a school of hard knocks." It is a process that educates through experience, and has been raising a preponderant majority from the lowest levels of living to intermediate levels in one to two generations. Because entry of poor immigrants is bitterly opposed by peoples in developed countries, such an observation would be highly controversial among the sponsors who pay the salaries of these international civil servants.

### Conclusions for Investigators

Large communities require more careful organization of knowledge about the stocks and flows essential to sustainable futures. Standard money accounts are used to *conserve capital*. The conservation principle applied to *energy flows* especially fits urban communities,



thus allowing a calculation of wastage. Similarly, the conservation of water and other critical materials enables the prevention of waste in times of great scarcity. But the conservation principle embedded in existing account schemes does not account for the power of information and innovations in creating new stocks of knowledge from which new forms of sustainable development emerge.

Accounts for costing human time and attention are quite new, requiring reinterpretation in the best of all conditions when work becomes pleasurable, and therefore regarded as part of consumption. Limits, however, are set up by life cycle norms, such as age- and gender-based roles (e.g., reproduction, retirement), or life expectancy. Altogether, these accounts are used to represent the social surplus available to members of the community during their Life Cycle (Figure 3). The principles are relatively straightforward, but the data are seldom available as yet in a useful form.

Ecological outputs can be combined in the form of *voluntary public transactions* with economic, social, cultural, physical, political, spiritual, esthetic, and environmental dimensions. Voluntary actors hope that their actions will lead in the direction of improved *quality of life* and personal *happiness* (win-win). We are learning to construct indicators of these conditions at the community level, but much more needs to be known about how to inform actors so that the outcomes are sustainable (win-win-win). Known intervening factors are health, risk perception and conflict resolution, but other factors (privacy demands, for example) may come into focus. A huge opportunity exists for lasting improvements by transferring new knowledge generated from local forms of community design, new forms of management, as well as scientific innovation.

Stocks and flows must increase over time to substitute for the disappearance of non-renewable resources. The stock of community knowledge, the flow of information within and between communities, along with actual incremental increases in capacity for information flow and knowledge, represent real progress toward sustainability, so we should be calculating the most economical means in terms of resources for acquiring it. Computerized data processing and records management enable another feature of long-term sustainability—the conservation of *information*.

The community ecology framework presented above promises to produce a comprehensive and appropriate set of accounts for dealing systematically with the long term community life. It will probably emerge as the dominant paradigm for planning urban communities,

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because it can distinguish dangerous, wasteful programs from those that are sustainable.

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