Building Materials in a Green Economy:

Community-based Strategies for Dematerialization

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BUILDING MATERIALS IN A GREEN ECONOMY:
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Abstract

The building industry can be a strategic fulcrum for green economic conversion in society as a whole. Not only is it decentralized, present in every community, but the built environment constitutes everyone's personal habitat and has a direct bearing on all people's well-being. Equally significant, it is responsible for perhaps forty percent of the economy's materials and energy throughput, and so changes in building have great potential impacts in extraction, manufacturing and waste management.

Creating a green economy is not just about encouraging environmental protection, but about establishing closed-loop ecological alternatives in every sector that substantively contribute to both dematerialization and detoxification of the economy. Besides creating cyclical material flows, green development is also geared to increasing production of service (i.e. directly meeting human and environmental need) rather than material output. What would the role of building materials be in an ecological construction industry geared to service and cyclical flows?

This dissertation surveys the many dimensions involved in transforming materials use in building to create a closed-loop service-oriented building industry. The thesis includes chapters on, respectively, the evaluation, production, consumption, recycling, and regulation of building materials. It attempts to explore ***potentials*** in these areas by

simultaneously reviewing the practical initiatives ***already taking place*** in green building—including life-cycle analysis, green building assessment, eco-labelling, eco-industrial development, clean production, design-for-disassembly, deconstruction services, natural building and alternative materials, product stewardship, extended producer responsibility, building code reform, green procurement, collective consumerism, and green market creation. How can these many fronts be combined and coordinated to comprehensively green the building industry and create healthy sustainable communities?

Besides surveying key developments in these crucial areas, the thesis attempts to clarify priorities for green development that cohesively link these realms in community economic development strategy. The central role of information, knowledge and education is highlighted.

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The Purpose of This Study

Materials are the stuff of economic life in our industrial world. They include the resource inputs and the product outputs of industrial production. How we handle them is a major determinant of true economic efficiency, real prosperity, social justice, our personal health, and the health of the natural environment. Materials are, moreover, far more than resources or products. They are gifts of nature, and substances of Gaia's Body. How we relate to materials—in their production and their consumption—is one of the best barometers of our fundamental relationship to that which gives us life. Not coincidentally, it reflects our relationship to ourselves, our creativity, our work and possibilities for self-actualization and community development—a theme I will emphasize throughout this thesis.

This dissertation is about building materials: about how we use them now, how they might be used more appropriately, and the process of getting from here to there. Our current use of materials is running down natural systems, destroying community, debasing work, and suppressing all kinds of possibilities for real development. To remedy this, we need to conserve materials, reduce their unnecessary use, produce them more benignly, make them last longer, and recycle and reuse them. We also need to develop community consumer initiatives and regulatory processes to support these reforms. Therefore I have organized this work in chapters to separately deal with evaluation, production, consumption, recycling and regulation of building materials—with the intention of clarifying the relationship between these realms, and therefore contributing to possible economic conversion strategies linking these areas. The role of information and education will be highlighted as a crucial connecting thread.

Building is a pivotal sector. It is responsible for a vast quantity of the industrial economy's material throughput—around 40 percent (Adriaanse, Bringezu, & et al, 1997). North American buildings absorb about 65 percent of the continent's electricity and generate about 30 percent of greenhouse gas emissions (U.S. Department of Energy--Energy Information Administration, 1999, 2001). 60 percent of the zone-depleting substances used in the U.S. come from building construction and systems (Wilson & Yost, 2001a).

Building materials, therefore, are important because of the immense social and environmental impact of extracting, processing and maintaining them. But buildings are also our personal environments, products in which we are constantly immersed. As Churchill said, "we shape our buildings and our buildings shape us." Building materials surround us, and (unfortunately) are literally part of the air we breathe. Compared to most other materials in our world, they are also much longer lived, with a much longer use phase. The industry is not centralized in one place but exists in virtually every community. It is a "service" industry but is also a major user and generator of material resources, and has important connections with manufacturing and other industries. Our relationship to building materials is thus a major influence on our economy, the natural world, and our personal and spiritual well-being. It is not possible in this thesis to deal properly with the many questions of urban design, some of which were on Churchill's mind, and others that are essential to positive ecological relationships. Questions of spatial design are absolutely central to green alternatives, and they will be touched in at various points in this thesis. But I also want to put some focus on product and economic system design to create a larger synthesis which both clarifies the situation of the building industry today and some fruitful priorities for making positive change.

This dissertation is, however, not simply about building materials. I am perhaps equally interested in what the building industry can tell us about a potential green economy, as in what green economic analysis can tell us about building and building materials. So this look at building materials serves as a kind of case study of postindustrial economic development. Until recently the focus of the green building movement has been much more on energy than on materials. The same can also be said for the environmental movement generally. Energy is a justifiable concern, but a narrow energy focus sometimes runs the risk of preoccupation with efficiency—avoiding consideration of the purpose of what we are doing economically. Materials are energy, but embodied energy—energy bound up with and expressive of human purpose. They are more transparently reflective of the end-uses of the economy—and end-use is a crucial starting point for ecological design.

The building industry, especially that related to materials, is expressive of important trends in green economic development. The role of information and knowledge, the appropriate forms of production and recycling, and even emerging forms of civil-society-based regulation are graphically manifest in building, and often substantially more advanced than in other sectors of the economy. Most generally and importantly, questions of design are keys to postindustrial economic transformation, and many key design relationships are often dramatically expressed in the built-environment and the building industry.

In my earlier book, *Designing the Green Economy* (Milani, 2000), I described how we are in the midst of a major historical transition. This makes it ever more imperative that we consider the building industry in the context of the economy as a whole. For this reason, I will provide an overview of green economic change, building on the principles outlined in my earlier book, with the building industry as a kind of case study of ecological transformation. In this sense, this work takes a step beyond *Designing the Green Economy*, which surveyed key economic sectors in a very general way. In this thesis, I have the opportunity to look at how the principles of green economic development apply to a particular industry—an industry which nevertheless involves various sectors of the economy. I will look at the evaluation, production, consumption, recycling and regulation of building materials, in ways that point to possibilities for community development. My belief is that this study should be useful not just for those involved in building, but for anyone interested in how fundamental social change can take place. In my previous book, I argued that such change requires a large vision of what green production-consumption should be, and the systematic creation of enterprises that gradually take us closer to those ideals. The attempt here is to define that vision for building while calling attention to efforts already underway to realize aspects of this vision.

I will look at materials use as a system, echoing the insight of ecologist Barry Commoner (Geiser, 2001, p. xi) that our existing economy's destructiveness (both environmental and social) arises not primarily from a failure of design, but from a *principle* of design based only on economic self-interest and technical feasibility. That is, the values behind the design are wrong-headed, partial and destructive. For this reason, I begin my examination of building in Chapter II with the value revolution taking place in construction and how it relates to appropriate patterns of economic design summarized in this chapter.

Throughout this work, I will be concerned equally with the amount and the composition of materials. We are currently using too many of the earth's resources and we are using them to produce too many toxic substances. In particular, there are new synthetic toxins and classes of materials (e.g. organochlorines) that are intrinsically destructive to human beings and ecosystems which can not break down these persistent and accumulative substances. A green vision, therefore, geared to transforming both the quantity and quality of materials, involves the twin tasks of dematerializing and detoxifying the economy. We must do more with much less, and produce much safer environmentally-benign materials. The key principles of green economic design, dealt with in my earlier book and summarized here, will be invoked to show how this dematerialization and detoxification actually takes place for different circumstances, sectors, and materials.

Essential to a transformation of materials use is a radical redefinition of economic development. Even a superficial assessment of materials-use signals real danger and the need to reassess long-held notions of progress and growth. Open-ended economic growth has always been held to be an unqualified good, providing the possibility of higher living standards for all without having to redistribute wealth and power. But the finiteness of the biosphere has begun to dramatize the inherent limits of material accumulation. Early (1970s) environmental concerns focused on the exhaustion of non-renewable resources, but more recently experts and activists have realized that the more serious problem is the effect of economic growth on natural processes that until now have been renewable and self-regulating. The way we use resources is undermining the basis of life. Over the last 50 years, industrial development has seriously degraded one-third of the planet's arable lands, while eliminating one-third of tropical forests, one-quarter of available fresh water, one-quarter of fish reserves, and innumerable species of plants and animals vital to ecological stability. Another crucial impact, climate change, threatens to take on a life of its own and accelerate all the aforementioned negative impacts. And, on top of this, new kinds of persistent accumulative toxins further undermine human and environmental health (McGinn, 2000).

This environmental crisis has, of course, major implications for social development. My angle on this is to focus on the role of our very structure of resource use and materials production. In underdeveloped and impoverished countries, where most people do not have their most basic needs met, it is not possible to assume that conventional resource-intensive market-driven economic growth is the answer. These countries need more direct (as opposed to trickle-down) solutions, and ones that employ and engage people, not displace them. And they need work that helps them restore ecosystems often degraded by their countries' status as resource-extraction or cheap-labour zones for the industrialized countries. Throwing one's lot in with the global economy stands to be a risky game, since all indications are that the polarization of rich and poor is intensifying with globalization (Milani, 2000; Rees, 2001).

As I tried to show in my earlier book, resource- and capital-intensive industrialization was structurally based not only on the invisibility of many resources, natural processes and ecosystem services, but also on the invisibility of certain kinds of work. In particular, there was the work of women, who were identified with the home and spheres of consumption and reproduction. This was essentially people-oriented service work, the very kind of work which is so important to eco-community development today. But the remedy to patriarchal economics is not necessarily to absorb women into the market, just as our environmental dilemmas will not be solved simply by commodifying all resources and ecosystem services. Certainly markets need to recognize previously unvalued services, both human and ecological, but translating all value into monetary value is not the answer. We need ways—like indicators—to let social and ecological values speak for themselves, and we need to find other forms of support and recognition for regenerative services that do not corrupt their qualitative goals. In fact, sustainability may require that markets themselves be subordinated to larger values than profit and accumulation.

This means not just imposing protectionist limits on industrial growth. Limiting development is not the answer, but rather redefining it: from a narrow focus on production and accumulation to a direct focus on people's needs, on service, and on regenerating natural systems. It is a movement from quantity to quality. This has tremendous relevance to underdeveloped countries and international development, and for women, who have long been "specialists" in non-material development. It also has great relevance for the labour movements in the developed countries who are finding that the "social contracts" attained after WWII are under attack as the costs of materials-intensive development are coming due. Full employment is no longer the priority it once was in the rich countries, and as knowledge-based jobs are concentrated into narrow bands of the workforce, the vast numbers of new jobs are deskilled McJobs (Sklar, 1995, p. 26). This is not the kind of service work that green economists advocate. But people-intensive ecological work is precisely what could build a new kind of progressive union power.

This dissertation cannot hope to properly treat the implications of dematerialization and green development for the labour movement, for women's equality, or for global poverty and international development. But it is important to recognize that there is a close relationship between social and ecological exploitation, and social and ecological development. Understanding the industrial economy's relationship to materials and resources can make a great contribution to understanding the status of women, of workers and of the Global South in social change today. While this thesis cannot hope to explore all these things, I believe my treatment of green economic potentials can be useful to those who wish to do so.

Although the primary focus of popular environmental awareness—and green building—has been on energy, it is our relationship to materials that will probably have the most significance for green economic transformation and the establishment of sustainable societies. Cutting-edge thinking on green economics has accurately identified industrialism with material accumulation, and postindustrialism with what has been called dematerialization of the economy. Green thinkers recognize that the growing importance of knowledge, information and culture should make it possible to displace materials and energy from production with human intelligence and ingenuity. This would allow us to satisfy more basic human needs with far fewer resources. It would ostensibly also allow us to fit human economic activities within natural processes without disrupting them. But all this would entail fundamental changes in the form, content and driving forces of the economy—the subject of *Designing the Green Economy*.

Part and parcel of this dematerialization are the two other characteristics of authentic postindustrial development: detoxification and decentralization. Detoxification means the production and use of more benign materials—materials that are not only healthier, but that can also be cycled and recycled in closed loops, and eventually safely returned to nature as compost. Closed loop organization saves resources and thus helps "dematerialize". Decentralization is a tendency of advanced economic development that we already see in energy technologies—for example, the decline of the massive generation utilities like Ontario Hydro. Decentralization is also visible in more subtle ways in manufacturing processes; but more radical forms of it are necessary to establish tight loops of production and consumption, to make "waste" into a resource, and to make the most of regional materials. Decentralization is, however, also important because new forms of qualitative wealth based on service (and on the direct production for human need) must necessarily be community-based. Community participation is, in a sense, a technical necessity for achieving new levels of eco-efficiency.

The purpose of this study is to look at the role of building materials in an ecological economy, and to consider the practical ways by which dematerialization might take place—and is taking place—in the building industry. A related question is: what would a building industry based in service—the key attribute of postindustrial green economy—look like? This, of course, goes far beyond construction—since it has major impacts on manufacturing, extractive and disposal industry—and it also requires basic changes in the goals and driving forces of the economy. I am particularly interested in the implications of such change for community economic development.

Like my earlier book, this dissertation is about potentials: the most appropriate way of doing things, given our level of development. But as in my earlier book, I want to explore this by highlighting the practical initiatives already taking place that are contributions to this new level of production and consumption. I want to strike a balance between theory and practice, large vision and practical methods. In that book I looked at the underlying principles and ultimate potentials of green development, and argued that they constitute a new and holistic paradigm of post-materialist economic development. In this work I want to demonstrate this even more graphically and specifically, as it applies to building materials. In this sense, this is a work of theory in green political-economy. While contributions to the new paradigm are multiplying by leaps and bounds every year, so far as I know this is the first general synthesis of this sort applied to building materials—covering production, consumption and regulation.

While my emphasis on principles and potentials makes this is a work of theory, it is also intended as a work of policy or economic strategy. By highlighting best practices in key areas, I want to make it useful for builders, developers, tradespeople, designers, planners, policy-makers, community economic developers, environmentalists, ethical investors and others. I want to suggest ways by which communities can (or are already beginning to) spawn green industry, turn waste into wealth, generate healthy work, create markets for eco-products, and simultaneously move to preserve or regenerate their natural environments.

Personal Background and Context

My interest in building materials is the organic expression of my dual interests in building and political-economy. Longtime concerns with social change led me in the late seventies to search for practical skills that could help create a new world. Ecology and appropriate technology seemed crucial elements to creating not only healthy new economic relationships but also an economic basis for decentralized participatory politics. The building sector seemed to be the nexus for the most exciting of these green alternatives. Writers like John Todd (1994), Christopher Alexander (1979; 1977), Delores Hayden (1984) and Sim Van der Ryn (1986) were intellectual influences who dramatized the importance of design in general, and the built-environment in particular.

My searching confirmed what Alexander said: that most architecture schools were not teaching the crucial design skills; and I chose to develop practical skills as a builder, augmented by informal education as a designer. I did a four-year carpentry apprenticeship, while taking side courses in passive solar design and energy-efficient building. At the same time I devoured as much literature as I could on vernacular design, eco-architecture, green planning, and appropriate technology—even as I tried to keep up with general knowledge in green economics and political-economy.

My practical work as a green carpenter and builder—in Vancouver, Nova Scotia and Toronto—was in itself an education on the need for a new relationship to materials. In our industrial economy, materials and resources are substantially undervalued; their market prices do not reflect their full-costs to society or nature. Although building is a relatively labour-intensive industry, materials are still far less expensive than labour, and in order to survive in a very competitive industry, there is always the temptation for the contractor to use more materials to cut down labour time. For example, if my partners and I decided to reuse old 2x4s on a job, would we charge the building owners for the time to pull all the old nails, inflating their costs, or would we would we donate the time ourselves, essentially subsidizing the job with our own meagre incomes? Invariably it always seems cheaper to dump the demolition and use new materials—even though society and the environment pay dearly for such behaviour.

Even when more enlightened environmental behaviour might pay off in monetary terms, it was often very difficult to know what materials were more ecological and where they might be obtained. Despite all my books and magazine subscriptions, it seemed every job had to be individually researched (again, for free unless one wanted to price oneself right out of a job). There was no basic directory or central clearinghouse for information on green building materials, and in the few cases where there was, it was typically a thousand miles away, and therefore useless for guidance on local building. Green building, green materials and green economics are all very specific to place. An organic tomato that has to be shipped 1500 miles is not an ecological food. The same is true of an “eco-paint” made with rainforest resins and manufactured in Germany.

These dilemmas eventually spawned the Eco-Materials Research Project in Toronto. Although initiated by our Green City Construction company in 1994, it became an expression of the informal network of green building people in Toronto. Since then, the Eco-Materials Project has been the primary focus of my building industry work. It has been an excellent introduction to the complexity of green product evaluation, and to the difficulties of creating new kinds of markets for green production.

Besides the practical influence of construction on my concern with materials, there has also been an intellectual and political thread, expressed in my study and writing on green political-economy. All roads—professional, construction, political, economic and environmental, activist and intellectual—have led to Rome, i.e. to materials, as a key to economic change today. Since the mid-seventies, ecology has played an ever-greater role in my political and economic thinking. By the nineties, I had become aware that the most crucial distinction between industrial and postindustrial development is expressed in their respective relationship to materials and human creativity. That is, industrial development has been essentially a phase of quantitative or material development: what I call thing-production. By contrast, postindustrialism suggests unrealized but latent potentials for qualitative or cultural development—post-materialist development, or people-production. When these potentials emerge, material things remain vital concerns, but material production can no longer be an end in itself—it must become simply means to the end of satisfying real need. This is the only way we can survive in a finite world, and it is the only way the new forms of eco-efficiency (which are premised on an end-use approach) can be tapped. Such a reversal of means and ends is to a large extent possible because the industrialization of culture has changed not just the outputs, but the inputs of production. In contrast to 19th century industrialism, the key factors of production are no longer physical capital and routine labour, but human creativity and ingenuity.

My previous book makes this argument in more detail, and I will elaborate more later in this chapter. Here I want only to provide some personal context that illustrates my concern with materials. I want to make clear that this work is intended to contribute to knowledge in both political-economy and building—as well as in the many policy domains in between.

Largely because of the scope of my work, and because it combines theoretical and descriptive elements, my research method has been somewhat eclectic. My earlier work provided a theoretical framework to guide further exploration into industrial ecology and green community economic development. But I have also relied on a variety of sources—library research, the internet, interviews and direct observation/participation of local initiatives. It is interesting to note that so much of my library work was also internet research. While website browsing was a tremendous source of discovery, many of the most useful documents I have found through the University of Toronto library system have been obtained electronically right at my desk.

Economics, Efficiency and Invisibility in Industrial Capitalism

To appreciate possibilities for a more ecological and developmental use of materials, we must understand the role of materials within the industrial economy over the past 200 years, particularly their relationship to labour, to information and science, and to the satisfaction of human need.

As Richta et al (1969) have shown, the industrial revolution was initially far more economic and technological than scientific, marked by a fantastic mobilization of resources and a particular organization/simplification of the labour process. This technological mobilization was made possible by an economic revolution which turned the means of production into forms of capital, making the accumulation of money virtually synonymous with technological revolution—and vice versa. The permanent economic growth resulting was totally unprecedented even for capitalism—which in its mercantile forms was essentially a process of unequal exchange. Capitalist growth in industrialism depended on new concentrated sources of energy which could make possible the system's amazing mobilization of resources. First it was water and steam power, but ultimately growth depended upon the concentrated "solar" energy of fossil fuels. As Lyle (1994, p. 29) has emphasized, this centralization and concentration of energy generation effectively shifted prime productivity from the landscape to machinery (precisely opposite what he argues postindustrialism must do: i.e. disperse energy generation and flows into the landscape, not through a return to peasant agriculture, but via eco-design, and increasingly human-scale advanced technology).

The popular mythology is that industrialism constituted the highest level of economic efficiency ever seen. But in fact, as Geddes (1915) emphasized almost 100 years ago, early industrialism employed a crude "paleo-technology" that, from an energy-in/energy-out perspective was quite inefficient. E.F. Schumacher (1974) pointed this out in citing garden agriculture as being far more thermodynamically efficient than corporate agribusiness, which is capital- and resource-intensive. What gave industrialism its power was not its efficiency, but its ability to process vast amounts of nature's materials with its new energy technologies and division of labour.

In the last several decades, many writers have pointed to the dependence of these arrangements on the invisibility and undervaluing of both nature and certain kinds of human labour. On one hand, undervalued or unvalued materials have been churned through the industrial megamachine, even as ecosystem services—which clean our air and water and absorb wastes—have (until recently) remained completely invisible. On the other hand, this use of “free” materials has allowed an organization of the labour process that has kept workers under control. Productivity for the industrial economy has generally meant “labour productivity” rather than resource productivity, and technological innovation has been geared far more toward the displacement of labour than of materials.

Industrial capitalism has had to adapt these relationships to new circumstances as industrialization inevitably moved into the realm of culture: via white-collar work, science-based production, mass education, service industry, etc. But despite growing potentials for qualitative development, industrialism has still maintained its essential character of a system of quantitative development and material accumulation. Key elements of nature and of human work remain invisible and/or undervalued. Despite a concern with cultivating consumption, the system still remains one of production-for-production’s-sake (or for-money’s-sake). This is especially problematic today because of the destructive impacts of open-ended growth. At least the quantitative accumulative thrust of early industrialism, however exploitative, served to meet society’s most basic needs for food, shelter, clothing and basic infrastructure. Today, no such case can be made—material accumulation is eroding the planet’s capacity to provide for the basic needs of millions of people. As elaborated in my previous book, quantitative development is paradoxically reinforcing scarcity, primarily in the interest of maintaining the power of industrial elites.

Nevertheless the popular mythology of industrial efficiency is widely believed despite the revelations of economist Robert Ayres who estimates that only 6 percent of minerals and renewable resources extracted gets embodied in final products—that is, 94 percent is waste (Whitaker, 1994, p. 30). Amory Lovins goes further, writing that that the US economy converts only about 2 percent of the energy it uses into services, wasting the other 98 percent. Along with co-authors Hunter Lovins and Paul Hawken (1999, p. 52), Lovins argues that only about 1 percent of all materials mobilized to serve North America is actually made into products and still in use six months after sale. They add that only 2 percent of the total waste stream is recycled.

These irrationalities can exist primarily because what is considered "economic" omits full costs—maintaining industrial forms of invisibility. The official cost of materials has simply been the cost of extracting and processing them—with their price determined by this extraction cost coupled with market demand. In real terms, this has amounted to a massive subsidy to the market system by nature. This has continued to erode the power of organized labour, still subject to labour displacement and de-skilling despite worldwide population increase, a situation aggravated by globalization and capital mobility.

The official invisibility of nature's materials and services to the economy has therefore hidden important costs. Economists now call them externalized costs (or "externalities") since, even though they do not affect a firm's balance sheet, they tend to show up elsewhere—as health costs, costs of state environmental cleanup, future costs created by wasting and depleting resources, etc. For a long time, these externalities were small enough to treat as if they didn't exist. Nature seemed to be endlessly plentiful, and cheap labour always seemed too scarce. Labour also had the inconvenient inclination to demand at least minimal remuneration for its services; nature was always more acquiescent. It was handy that energy and resources—as expressed in technology or physical capital—could substitute for labour, particularly skilled labour. The use of drastically undervalued nature, therefore, was economic not simply in providing a subsidy to the market economy, but also in keeping down labour costs and keeping organized labour under control. (I will look more closely at the implications of this relationship to labour in the next section.)

For millennia the human economy remained quite small relative to the scale of the planet's ecosystems. Today, however, the very scale of the economy means that we can no longer ignore externalized costs. Such costs reflect new forms of pollution and environmental destruction that threaten not just local environments, but the integrity and balance of the entire planet's biosphere. Previously, local or regional communities may have been threatened, but today the scale of destruction threatens the survival of the entire human species. It is not only that many of nature's materials are becoming scarce—requiring ever more destruction to extract them—but the biological "sinks" that have absorbed industrial waste are increasingly incapable of functioning any longer. Many of "ecosystem services"—including pure air and water and the absorption of humanity's waste—can no longer be taken for granted, since they are not only valuable, but irreplaceable.

Economic Growth and the River Economy

Today, our overpopulation, unemployment and environmental problems dramatize that labour is the plentiful economic factor and nature is the scarce one. And yet, capital-intensive, labour-displacing development continues—still based on the official invisibility of biological sources and sinks. It has been estimated that humans now monopolize 40 percent of the world's land-based net primary production (NPP), the amount of energy annually converted from sunlight into food by the world's plants. According to William Rees (2001), based on estimates of sustainably productive ecosystems, humanity has already "overshot" the long-term human carrying capacity of the Earth by up to 40 percent; while North Americans are using three to four times more per capita than their fair share of the earth's sustainable resources. The New Economics Foundation's Living Planet Index, developed with the World Wildlife Fund, estimates that humanity has destroyed one third of nature's resources over the last 30 years. The growing destruction of natural habitats has generated a rate of biodiversity loss that is now 1,000 times the natural "background" rate (Rees, 2001). The economic costs of climate change have doubled for each of the last few decades according to the insurance giant Munich Re. According to economist James Robertson (2000), if that pattern continues, by 2060 the costs will be greater than total Gross World Product.

The invisibility of nature's materials and services has permitted a particular structure or organization of the industrial economy that has been called a "river" economy (Stahel, 1998). In contrast to the workings of nature which cycle and recycle like ecosystems in a lake, resources in the human economy move in a linear flow, more like a river: from extraction, through processing, distribution, use and finally to disposal. Because of the severity of our environmental crisis, changes that do not alter this organizational structure will be hopelessly insufficient to establish sustainability. And yet, despite growing environmental costs and concerns, most environmental measures have left this structure intact. Despite the growth of recycling over the last 30 years, in North America only about 25 percent of municipal solid waste was recycled by 1995, and less than 2 percent of the total waste stream (Gardner & Sampat, 1998) .

Incineration—an option increasingly pushed by corporations and technocrats as a solution to the waste crisis—is an end-of-pipe solution to this crisis that avoids dealing with fundamental problems by extending the River Economy. Experts and environmentalists have documented the waste intrinsic to incineration—which in the case of paper, for example, squanders four times as much energy as recycling. Incineration also aggravates problems with toxic waste. Incinerators are notorious sources of mercury emissions and dioxins, and while reducing the volume of solid waste, they concentrate toxicity into the remaining ash, which becomes an even more difficult disposal problem (Platt, 2004). Perhaps most importantly, incinerators are very expensive and reinforce the capital-intensive nature of local economies. Municipal investment in incineration inevitably pre-empts more people-intensive community-based "closed-loop" development in recycling, reuse, repair and remanufacturing—all activities essential to an ecological closed-loop "lake economy".

As I mentioned briefly in the previous section, postindustrial productive forces based on knowledge and human creativity should offer possibilities for the "dematerialization" of production by doing more with less. It might seem that the current information revolution and the rise of lighter stronger materials would make it possible for advanced economies to use fewer materials. But capitalist tendencies of constant growth have more than offset these potentials. Materials intensity—the tonnage of material used to generate a dollar's worth of output—did in fact decline by 18 percent between 1970 and 1995 (Gardner & Sampat, 1998). But materials production and consumption have both risen dramatically over the past century, with total consumption of materials swelling by 67 percent between 1970 and 1995. This is by no means due exclusively to population growth. In the last few decades, with the advent of supposedly postindustrial economies, per capita materials consumption has continued to rise, even in the developed countries. Between 1963 and 1995, world population grew by 1.8 times, while total production of primary materials more than doubled—from 4 billion to 10 billion tons. (Figure 1)

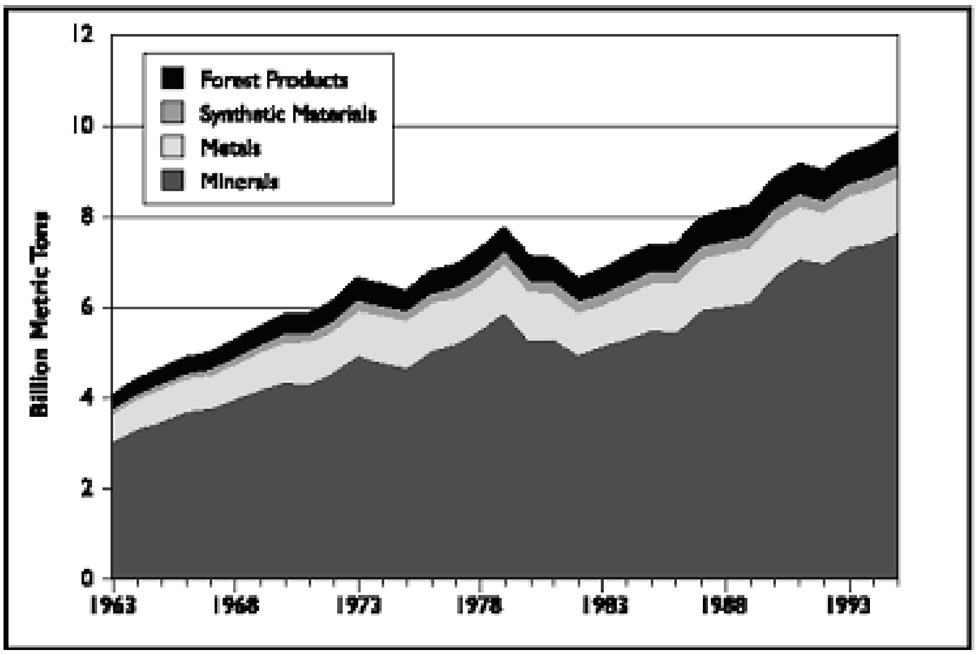


Figure 1. World Materials Production 1963-95
Source: Young, 2000

Mathis Wackernagel and William Rees (1996), developers of the "ecological footprint" environmental indicator, calculated that if everyone consumed like North Americans, we would need the equivalent of three planet Earths. Germany's prestigious Wuppertal Institute calculated that global sustainability would require a 90 percent— or Factor 10—reduction of materials use in the developed countries (Schmidt-Bleek, 1994). This would be the minimal level needed to stabilize climate, maintain an acceptable level of species diversity, and allow natural systems to regenerate. Many other commentators consider this a conservative estimate.

The basic problem behind this consumption is not primarily inefficiency, but rather open-ended economic growth. As Anders Hayden (1999, p.26) has pointed out, without a commitment to reduce our demands on the Earth, continuing growth of the economy can offset even substantial efficiency gains. He cites advocates of Factor Four efficiency policies who have pointed out that "with a growth rate of 5 percent a year all the gains for a factor-four [i.e. four-fold] efficiency revolution would be devoured in less than 30 years. At a more moderate 3 percent rate of economic growth, the efficiency revolution would be entirely undone in a mere 47 years." William Rees (1995) has even pointed to the "rebound effect" of efficiency gains which can stimulate even more consumption if the system is not consciously concerned with abating overall resource use.

It is no exaggeration to say that this profligate growth and consumption is the single most important source of all our environmental problems and many of our social ones. Most of our pressing environmental problems are intimately connected with our use and misuse of materials. The depletion of the ozone layer, climate change, disruption of the global nitrogen cycle, the narrowing of species diversity, the destruction of the fisheries and the many forms of toxic pollution—are symptoms of either overuse of nature's materials, or insensitive means of extracting, processing and using them.

Eco-footprint is an environmental indicator that measures an economy's (or a community's or an individual's) overall environmental impact in terms of the territory needed to support their consumption. Materials use strongly influences the size of a population's footprint: in the U.S. case, materials are conservatively estimated to account for more than a fifth of the total footprint. (Fossil fuel use and food production are other major components.) And other research implicates materials even more heavily. When measured by weight, materials account for 44 percent of the United States' resource use, 58 percent in the case of Japan, and as much as 68 percent in Germany (Gardner & Sampat, 1998; Wackernagel & Rees, 1996).

Key Sectors: Extraction Industry and Petrochemicals

In considering the problems of the River Economy, and the challenges for using fewer resources (dematerialization) and making them more benign (detoxification), two key sectors of the industrial economy immediately come to the fore: extraction industry and petrochemicals. Not incidentally, the current character of both sectors are made possible by fossil fuels.

Resource extraction is especially implicated in environmental destruction. Mining may be the world's most destructive industry, moving more rock and soil (an estimated 28 billion tons) than all the erosion caused by the world's rivers. The industry today is more destructive than it ever has been. It favours surface mining over underground mining techniques, which generates many times more waste. Canada's mining wastes are, for example, 58 times larger than its municipal refuse (Gardner & Sampat, 1998). In the US, mining has contaminated over 19,000 kilometers of the nation's rivers. Declining ore grades—or "low-grading"—means that much more ore must be hauled each year to produce the same amount of metal. Over the 20th century, for example, copper production grew 22 times, and waste from copper production 73-

fold. The industry also uses far more toxic chemicals than ever before, presenting intractable toxic disposal problems.

The forest products industry is another culprit in the wholesale destruction of species diversity and ecosystem integrity, and as such is implicated in related problems such as CO2 emissions, climate change, flooding, soil degradation and the disruption of nitrogen cycles. Logging operations are usually the cutting-edge of industrial exploitation of the hinterlands—as logging roads pave the way for hunters, mineral prospectors, farmers and real estate developers. Deforestation is not only implicated in climate change—with the earth having lost over half of its forest cover in the last century—but it is now causing the loss of an estimated 5 to 9 percent of the world's species every 10 years. While wood can be a very durable and useful product, its current uses are suspect: almost 20 percent of all US lumber is used to make shipping pallets which are typically dumped after use; and nearly 40 percent of industrial timber goes into paper (Young, 2000).

Equally implicated with extraction industry in the destructive River Economy is another form of primary industry—the petrochemical industry. Environmental problems here stem not just from the amount of resources exploited, but by the toxic character of many industrial materials. Our current resource use is not just an expanded version of traditional materials use, but it is far more complex and poisonous. In 1900, humanity used about 20 of the 92 naturally occurring elements in periodic table; today we use them all. The new synthetic chemicals made from hydrocarbon feedstocks today present major threats to both human health and the global environment. Organochlorines are a particularly prominent and destructive class of substances which have been linked, among other things, to endocrine and reproductive system disruptions in animals and humans. Many of these persistent organic pollutants, or POPs, which are present in tens of thousands of synthetic chemicals, have been known to have delayed impacts, sometimes visible only after many years. They accumulate in fatty tissue and are passed up the food chain. The U.S. National Academy of Sciences reports that insufficient information exists for even a partial health assessment of 90 percent of chemicals in the environment (Jackson, 1996, p. 30). The US Toxic Release Inventory makes public just 7 percent of high-production chemicals, those used at 1 million pounds or more each year. And what little testing and evaluation is done on these chemicals, virtually nothing is known about the "synergistic effects" of these chemicals when they mix together in the real world (Colburn, Dumanoski, & Myers, 1996). Synthetic chemicals are the major source of epidemic levels of building-related illness, which the US EPA and World Health Organization both consider serious health problems. (These petrochemical-related problems in indoor environmental quality in buildings will be dealt with more specifically in Chapter III).

The refineries and chemical plants involved with these chemicals are among the industrial world's largest sources of hazardous waste and toxic emissions. Over 90 percent of US "Superfund" cleanup sites are petrochemical-related. According to Gardner and Sampat, there are some 40,000 Superfund sites, and the Environmental Protection Agency estimates that cleanup of just the 1,400 worst sites will cost $31 billion. The world situation is even worse. In a 1991 waste survey of more than 100 nations by the International Maritime Organization, almost two thirds said that hazardous industrial waste is disposed of at uncontrolled sites, and a quarter reported dumping industrial waste in the oceans (International Maritime Organization, 1995).

As I will argue—and then illustrate with specific reference to building materials—green economic development involves a drastic transformation—and downsizing—of these troublesome sectors. Sustainability depends, on one hand, on moving the bulk of extraction industry from the hinterlands to the cities where waste must be turned into a resource; and on the other hand, the gradual displacement of petrochemicals by biochemicals and by more natural, less highly-processed regional materials.

Bad Rules and Wrong Signals

The main reason why we do not produce and consume more sensibly is not primarily because of moral weakness or stupidity. It is because the incentives and disincentives built into the economy are wrong; they encourage waste, destruction and short-term profit, and discourage conservation, quality and long-term development. The range of things that constitute incentives or disincentives in an economy is, of course, vast. In this section, I will focus on two key areas—prices and subsidies—that can succinctly dramatize how skewed our economic priorities are. But in subsequent chapters, I will look at other important areas that are especially relevant to building materials like building codes.

Markets are supposed to allocate scarce resources by reflecting supply and demand in market prices. But more often than not, markets simply mirror power relationships among buyers and sellers, and neglect all sorts of relevant information. In the famous words of Ernst Ulrich von Weizsacker (1994, p. 117), "prices do not tell the ecological truth." One example of this is the long-term decline in the prices of most primary commodities that has so decimated the economies of resource-exporting nations in the Third World, even as stocks of those commodities have declined. The exhaustion of the Atlantic cod fishery is perhaps the best known Canadian example. In many cases, artificially low prices may encourage impoverished countries to intensify exploitation of diminishing reserves because they have no alternatives, and because international bodies like the IMF have forced these countries to abandon self-reliance in favour of exporting. This intensified exploitation further gluts the market and further lowers prices.

A big reason why prices have not reflected resource scarcity is because the prices of materials do not incorporate full costs. And the environmental costs of extraction industry have been increasing even as resource prices have been declining. According to John E. Young (2000, p.10), "The World Bank's index of metals and minerals prices…has declined 48 percent in real terms since 1960. The bank's index of nonfuel primary commodity prices has dropped by 55 percent over the same period." It seems clear that measures must be taken to make sure that prices do "tell the ecological truth", thereby allowing markets to encourage the right kinds of production and exchange. Ironically, some of the means by which costs could be more accurately reflected in market prices are being used to do precisely the opposite. That is, governments are using subsidies and taxes to encourage the destructive activities that should be discouraged. According to Myers and Kent (2001), what have been called "perverse subsidies" amount to $2 trillion worldwide, and they constitute 78 percent of all subsidies bestowed by governments. They total about 5.6 percent of the $35 trillion global economy.

Myers and Kent also tell us that the total of perverse subsidies is almost as big as the GNP of Germany; almost three times as large as global military spending per year; larger than the annual sales of the twenty largest corporations; four times as much as the annual cash incomes of the 1.3 billion poorest people; five times as much as the international narcotics industry; and half again as large as the global fossil-fuels industry or the global insurance industry. In a nutshell, they are large and no incidental part of the world economy.

Examples of these subsidies include subsidies for fossil fuels, road construction, tobacco growing, and all forms of resource extraction, particularly mining and logging. They can take a variety of forms: direct subsidies, expressed in tax breaks, free or cheap land and other public resources, regulatory exemptions, and special financing. Or they can be more indirect, as in the case of extraction industries that are permitted to impose the costs of environmental damage on communities, neighbouring property owners, local governments, downstream water users, etc.

Gardner and Sampat (1998, p.31) describe the use of tax policy to subsidize extraction at the expense of recycling:

> In Canada, for example, taxes are shifted away from virgin materials producers and away from disposal—and shifted onto recyclers. Indeed, tax rates for recycled material are on average 27 percent compared to 24 percent for virgin material, resulting in a $367 million (Canadian) disadvantage to the recycling industry. Unless the structural biases against recycling are uprooted, expanding recycling programs simply worsens the glut of secondary material and depresses prices further.

According to Myers and Kent (2001, p. 191), “All in all, a typical American taxpayer is paying at least $2,000 a year to fund subsidies that undercut both the nation’s environment and its economy. The taxpayer then has to pay another $1,000 to repair the environmental damage and to cover higher costs for food and other items."

Although special interests profit tremendously from perverse subsidies, they are also a holdover from a previous phase of industrial development, a "frontier' mentality that is no longer positive for economic development. It is ironic that these massive destructive subsidies are such a major part of a global economy that prides itself on "free markets". In fact, the markets are not free, many being rigged in favour of powerful vested interests. For this reason, an increasingly influential tendency within green economics is that of "natural capitalism"—which advocates a removal of all subsidies, allowing a "level playing field" for more ecological forms of production, like conservation and renewable energy. Some green economists, like Wayne Roberts (Roberts & Brandum, 1995), argue that corporate globalization itself is possible only because of massive subsidies for fossil fuels that make long-distance transportation artificially cheap. Roberts argues that, even without internalizing all the hidden costs of production, just the removal of subsidies to dirty energy would deflate globalization and spur the development of more efficient regional economies.

Changing the Rules: the Ecological Service Economy

The most general elements of an alternative to materials-intensive industrialism are implicit in the preceding critique: make the shadow realms of the industrial economy visible; emphasize people-intensive rather than resource-intensive development; and make human and environmental regeneration the primary goal of the economy.

From the standpoint of materials, there are two key dimensions to creating a green economy: (1) refocusing economic life on the selling of services rather than material products, and (2) reorganizing economic activities to either fit within, or mimic, the closed-loop design of natural ecosystems—a “lake economy”.

The first dimension has been called the “ecological service economy” and it constitutes a radical change in the rules of economic activity. In contrast to the pop notion of “service economy”, it refers *not* to the exporting of manufacturing to the Third World, but to a basic change in the aims of economic activity in every sector. It would transform all material output from being the end-goal of economic development into a simple means of meeting social and environmental need. These service-needs include nutrition, access (or mobility), shelter, health, entertainment, etc. Service is another way of describing “end-use”. As Amory Lovins (1977) initially described this approach to energy two decades ago, we should primarily be concerned with providing “hot showers and cold beer”, not power plants or fossil fuels. By focusing on the service-need desired, we can creatively discover the most elegant and efficient way (or ways) of meeting this need. Invariably, this allows radical reductions in the amount of matter and energy used, and, more often than not, a much higher level of quality.

It is possible to find examples of eco-service in the existing capitalist economy. For instance, there is the much-cited transformation of Xerox into a “document company” (or more precisely, a document service company) that designs its hardware for eventual disassembly and reuse. On the cutting edge of both green business and green building, there is also Interface Flooring, which is voluntarily implementing “extended producer responsibility” that drastically reduces waste. Another variation on the theme of eco-service is the energy service company, or ESCO, which carries out renovation and retrofit work on buildings. An ESCO doesn't sell you energy, but sells you energy savings, which amounts to the same thing—except that it does this for free since all the ESCO wants is a cut of the savings.

These service enterprises prefigure greater potentials. But for an entire economy to displace material accumulation with a service approach is a much more difficult proposition. Industrialism has always been based in growth and expansion. By its very nature, capitalism is focused, first and foremost, on exchange-value, the accumulation of money or capital. Any production of use-value (including what we would call service or end-use) is, by definition, a spin-off, by-product, or trickle-down of the accumulation process. Under industrialism, monetary accumulation has been closely connected with material accumulation and with production-for-production's-sake. We solve our access needs by mass-producing cars for profit; we solve our nutrition needs by mass-producing chemicalized "near-food" for profit; we meet our needs for shelter by mass-producing subdivisions and condominiums for profit, and so on. This has proven to be an incredibly wasteful, circuitous and often inadequate way of meeting human needs. By contrast, a service approach is one where we begin with the specific service-need in question, and work backwards to meet this need in the most elegant and efficient ways.

Most defenders of free enterprise would argue that this direct targeting of need reeks of socialism and would put too many limitations on freedom and the profit-motive. The effectiveness of an eco-service economy, however, would not depend on a centralized state, but rather on a comprehensive revamping of the economy's incentives and disincentives that, in operation, would likely be both more self-regulating and more participatory than our existing economy.

From a resource perspective, probably the most central elements of the service economy would be product stewardship systems based in extended producer responsibility (or EPR). EPR means that the producer of a product takes responsibility for full costs over the entire life cycle of the product, “cradle to grave”. It is a systematic extension of the “polluter pays” principle, in that, if corporations had to pay all the now-hidden costs of resource extraction and toxic pollution, they would quickly find ways of making things out of existing materials and out of non-toxic benign substances. Like Xerox, they would want to keep control of the materials involved in order to best conserve them, to lease their products, and to essentially sell service. Selling service also means that companies have to be especially sensitive to the specific needs of their customers.

As I discussed more comprehensively in my earlier book, when applied to an entire economy, the focus on service rather than accumulation represents a radical redefinition of wealth—from quantitative to qualitative. When society really begins to take consumption seriously, prioritize human need, and consciously attempt to increase the quality of life, all kinds of questions emerge about levels of need and about the difference between wants and needs. It raises questions about who we are, what the purpose of our lives is, and what our priorities should be, individually and socially. Answering these questions may not be easy, but few people have ever been given the opportunity to do so. (Industrial capitalism has tended to provide only materialistic avenues for fulfillment; it has assumed that “the answer is technology”, but forgot the question.) The biggest challenge is putting in place forms of political-economic participation and planning that can allow people to debate and define their vision, a vision that will actually be put in place.

One means of refining the vision and values that constitute qualitative wealth are indicators. There are many kinds of them—some very objective and some quite subjective—but they all have a crucial role in returning money to a status of a means of exchange rather than being the be-all and end-all of economic life. These indicators include indexes that measure and monitor resource flows in the economy; life cycle assessment (or LCA) that facilitates full-cost accounting for products and processes; and Sustainable Community Indicators (SCI) that synthesize vast amounts of information with the expressed priorities of specific communities. In subsequent chapters discussing building materials in ecological construction, I will look at the specific role of various kinds of indicators in exploring possibilities for a service economy in building. I will also look at policy, regulatory and fiscal tools (like tax shifting) that can be employed to incorporate full costs into market prices, thereby redirecting the profit motive to some extent.

Economic Biomimicry and Decentralization: the Lake Economy

The service approach is a way of changing the economic rules to facilitate the development of more integrated and efficient "closed-loop" processes—expressed in Stahel's comparison to lake ecosystems that cycle and recycle continually. Some of these forms of organization—like eco-industrial parks where firms use each other's by-products to eliminate waste—are examples of what Benyus (1997) calls "biomimicry".

That is, they mimic or imitate the elegance of ecosystems in order to reach a higher level of resource-productivity.

Vast possibilities exist, however, not only to imitate nature, but to actually integrate within it. The green economy should move like a sailboat in the wind of natural processes. This is true not only with renewable energy like solar and wind power, but also in the case of material resources and general patterns of production and consumption. An ecological economy must evolve in the direction of bioregionality, where economic and regulatory boundaries take the approximate boundaries of eco-regions.

It is because of this essential character of the green economy in re-embedding economic activities within natural processes that spatial design—and the built-environment generally—are so important. The late John T. Lyle (1994, p. 102) saw the green economy's relationship to the landscape as its most crucial feature. Industrialism, he wrote, signalled a shift in key sources of productivity from the landscape (mainly in the form of agriculture) to machinery and centralized energy supply. By contrast, he argued, authentic postindustrialism would disperse productivity over the landscape—in the form of eco-infrastructure, distributed generation of energy, urban agriculture, etc.

This tendency toward decentralization of production and power is the third "D" of postindustrial green economics that goes hand-in-hand with dematerialization and detoxification. It is an intrinsic tendency of knowledge-based technological development—as expressed in smaller more compact production systems (like steel mini-mills) and energy systems (fuel cells). But in industrial capitalism, it is limited by the system's basis in material accumulation and its resistance to an end-use approach. As

Lyle pointed out, the key forms of decentralization were not primarily mechanical, but spatial and organizational.

In order for a green economy to “do more with less”, proximity and multi-functional design are crucial. As permaculturalist Bill Mollison (1990) argues, oftentimes the greatest increases in a system’s efficiency can be obtained by a simple spatial reorganization of its components so that processes can do more than one thing at a time. In my previous book, I explored the role of ecological infill in creating more compact urban settlements that can clean water and air, cool and insulated buildings, and provide food, energy and even industrial feedstocks. I also looked at a negative example of how spatial organization affects efficiency: suburban sprawl. Suburbanization maximizes the consumption of virtually all materials. Not only does it create needless markets for otherwise superfluous consumer durables, building materials, automobiles and infrastructure. It also separates residences from workplaces, creating the need for otherwise needless transportation (with all its attendant pollution). This wasteful development helped generate massive economic growth after WWII, but today we are beginning to pay the externalized costs of such.

It is beyond the scope of this thesis to explore the role of spatial design of the built-environment—it is a major subject in its own right. But some appreciation of the central role of spatial organization in postindustrial economic efficiency is essential to understand the appropriate patterns of production and consumption of building materials. It helps us understand why reuse is so important, why regional materials are so crucial, why local production is essential, and how we might begin to create local markets for green production.

The use of local materials goes hand-in-hand with the use of natural materials. Not only does resource-productivity imply less highly-processed materials, but natural materials also tend to be less toxic. In eco-industrial production, “waste equals food”—in that every output is designed to be an input for some other process. If everything is “food” for something else, this suggests that this food must be non-toxic enough to be a nutrient for the system it feeds. And ultimate end-substances must also be able to be safely composted into the Earth itself.

In Chapter III on manufacturing, and then again in Chapter IV on recycling, I will explore more specifically production in the Lake Economy, both generally and as it applies to building materials. Now however, let’s look more closely at the general goals of dematerialization and detoxification.

Priorities for Dematerialization and Detoxification

Dematerialization basically means reducing the volume of materials moving through the economy, as well as reducing their speed of flow. Detoxification means changing the composition of materials, making them out of more benign materials and doing this in less poisonous ways.

Even if these processes don’t always require each other, in practice they complement each other in important ways. On one hand, as discussed above, the cyclical organization of the Lake Economy demands outputs that can be inputs for another process, and ultimately benign enough to be safely returned to nature. On the other hand, detoxifying the economy is much simpler and straightforward if the mass of materials flowing through the economy is greatly reduced.

Architect William McDonough captures the spirit of design to dematerialize in his oft-cited quote: “We should recycle, but it is not the first thing we should do, it is the last. Redesign first, then reduce, and finally recycle if there is no alternative.”(Thorpe, 1999, p.27).

John Young (2000) of the Materials Efficiency Project fleshes out this perspective with the following hierarchy of priorities for materials efficiency that I have adapted with some reference to construction materials:

1. Materials use avoidance: this includes scrutiny of consumption needs themselves—do we really need to build this?—and voluntary simplicity. It includes a focus on selling services, rather than products. It also includes the redesign of products, buildings and settlements to dispense with superfluous materials. The great efficiencies resulting from ecological urban design and mixed-use development are in this category. Certain new engineered wood products (if non-toxic) can displace massive amounts of conventional wood.
2. Increased intensity of product use: Product durability and all kinds of sharing are included here, and thus there is some overlap with category #1. Co-housing developments with shared facilities, for example, can substantially reduce the volume of materials use.
3. Reuse-based material cycles: Repair, reuse and remanufacturing are in this category, and in building there is vast potential for deconstruction (the disassembly of buildings) and the reuse of building materials. One step further is the design of buildings to be easily changed, repaired and disassembled.

4. Finally, there is materials recovery, or recycling. This tends to require more energy, but some form of recycling will be ultimately necessary for every material at some point in its life cycle, no matter how durable, reused, or shared it has been.

To detoxify the economy, design solutions also take top priority, since end-of-pipe clean-up strategies are not just logistically complex and expensive, but also inadequate. The spirit of a more workable preventative strategy is succinctly expressed by a paraphrase of ecologist Barry Commoner's (1990, p. 43) maxim: "The best way to reduce exposure to toxic chemicals is to not produce them in the first place."

Not using toxic chemicals presumes that there are realistic alternatives to them, and in fact there are. The use of these alternatives can become increasingly practical if a transition strategy is based on the specific character of groups of industrial chemicals. The key characteristics emphasized by Ken Geiser (2001), Director of Massachusetts' Toxics Use Reduction Institute, are degradability and toxicity. The spectrum along each axis produces four general categories. Each of these categories warrants a different strategy. Materials in Group 1 can and should be intelligently cycled between the economy and environment, since they are relatively benign, with many of them being renewable. Materials in the Group 2 should be recycled safely within the economy, and carefully returned to natural systems no faster than they are withdrawn. Materials in Group 3 must be very judiciously handled in use, recycled where possible, and thoroughly treated before being transferred from economic to ecological systems. Materials in the fourth group are inherently risky and destructive enough to have no justification for their use in a sensible economic system; they should be reduced, replaced and eventually phased out entirely. Needless to say, an ecological economy would evolve toward an ever-greater portion of its production utilizing Group 1 materials.

	⇦⇦⇦ More Degradable	More Persistent ⇨⇨⇨
↑↑ Less Toxic	Group 1: Degradable & Nontoxic • Cellulose • Carbohydrates • Carboxylates (soaps) • Biopolymers	Group 2: Persistent & Nontoxic • Iron • Silicon • Aluminum • Copper • Polyolefins
More Toxic ↓↓	Group 3: Degradable & Toxic • Acids & Bases • Esters • Alcohols and Thiols • Aliphatic Amines • Aromatic Amines • Ethylene/Propylene • Ethanol/Methanol • Phenols • Aromatic Hydrocarbons	Group 4: Persistent, Bioaccumulative & Toxic • Halogenated Aliphatic Hydrocarbons • Lead • Mercury • Cobalt • Cadmium • Halogenated Aromatic Hydrocarbons (PCBs, DDT) • Dioxins & Furans

Figure 2. Industrial Material Groups
Source: Geiser, 2001

In Chapter III, I will look more closely at detoxification strategies as they relate to more benign alternatives. But it must be emphasized that the "precautionary principle" widely advocated by the environmental movement (where new chemicals are presumed dangerous until proven safe) sounds far more realistic when we appreciate that most synthetic chemicals were not developed for a specific purpose. They emerged from the industry, and then uses were found for them. And most of them took over pre-existing markets from safer materials that worked perfectly well, but usually weren't as cheap (Commoner, 1990; Geiser, 2001). What's more, the toxic constituents of most common products (e.g. wood finishes or vinyl shower curtains) have absolutely nothing to do with their purpose, making them, in McDonough's words, "products plus". You got the use-value you sought plus harmful ingredients you didn't ask for and weren't informed were there. Such "crude products" are typical today, but this is simply bad design and very unnecessary (McDonough & Braungart, 2002, p. 37-38).

Building Materials in a Green Economy

As discussed earlier, building is a strategic sector in the economy and a key to social transformation for a number of reasons: the volume of materials flow; the role of the built-environment in daily life and every community; the importance of spatial design; etc. The uniqueness of the building industry presents many important questions about what an ecological economy would look like, and how it can be implemented, there. Building deals with very solid heavy materials, and relatively long-lived products, and yet the design and construction industries are essentially service industries. If a green economy is basically one that provides services, the question remains is how can building materials become strictly means to the end of providing services, rather than big sources of profitable sales in themselves?

This is a particularly difficult challenge when we recognize—as I described more thoroughly in my first book—that the fragmentation of the North American built-environment after WWII through suburbanization and sprawl was designed to maximize "effective demand" for all sorts of materials, especially building materials. The techniques of design and construction—from International-style curtain-wall office building to platform-frame housing construction—were premised on massive (undervalued) resource inputs and vast amounts of waste. This waste was a tremendous economic stimulus for a quarter century, but by the late seventies it was starting to become a burden on the developed economies. This situation has encouraged some positive changes in building over the past two decades, but mainstream practices change slowly, and there are also powerful interest groups that are still driving open-ended material development.

The modern green building movement had its origins in the appropriate technology movement of the sixties. The oil shocks and energy crisis of the early seventies launched a new solar and energy-efficient building industry. Throughout the seventies the new industry of consultants, designers and builders evolved from an initial focus on active solar technology, to passive solar design, and eventually to super-insulated construction, as there was an emphasis to make energy-conscious building more mainstream and affordable. The dramatic appearance of massively daylighted passive solar structures (which also often included giant greenhouses and masonry or water-drum thermal storage) gave way to the modest almost windowless boxes of the super-conserver variety. But many of the new super-sealed boxes of the late seventies and early eighties also were plagued with moisture-condensation and air-quality problems. This called greater attention not just to ventilation, but to the building materials that were outgassing toxic fumes.

These concerns with the toxic composition of materials gradually dovetailed through the eighties with growing environmental concerns about global warming and the embodied energy of building materials (the energy it takes to produce the materials), and also with the crisis of municipal landfill space—which focused concern on the recycling of building materials. By the early nineties, disciplines of "life cycle analysis" were attempting to quantify the total environmental impacts of building materials, and

"Advanced Building" programmes emerged to attempt creating fully ecological houses. By the mid-nineties, concerns with recycling spawned a new "deconstruction" industry promising major job-creation in addition to feedstocks for secondary materials industry. Meanwhile countercultural elements in building attempted to carry on the vision of the appropriate technologists of the sixties and seventies into the new millennium by experimenting with various forms of "natural building" like rammed earth and strawbales, along with a number of garbage-building techniques (e.g. "Earthships" built with old car tires).

Today, the green building movement is an exciting place, with a range of construction styles, philosophies and subcultures; different mixes of environmental, health and economic concerns; and greater involvement on all sides with questions of materials production. It is making more connections with other movements of the built-environment like those for affordable housing and historic preservation. The relevance of historical building preservation to green building's material concerns is particularly obvious. The preservation movement quietly took on mass movement status beginning in the late seventies, as great numbers of people reacted to urban renewal and suburban sprawl by becoming immersed in the rediscovery and defence of old buildings, buildings to be loved. Architectural historian Vincent Scully called it "the only mass popular movement to affect critically the course of architecture in [the 20th] century." (Brand, 1994, p. 88). This love for old buildings and old materials has deeply ecological implications, a fact reflected on the cross-fertilization of the green building and preservation movements, expressed in works like Steward Brand's *How Buildings Learn*.

In the preservation movement, (the best aspects of) cultural conservatism and environmental conservation meet.

As I will touch on in Chapter VI, there are also a number of economic initiatives that attempt to influence production through the creation of consumer demand. These tie in with efforts to change the economic incentives and disincentives of the economy to encourage both conservation and the use of green materials. And many of these also connect to efforts for community economic development based on decentralized ecological production and construction.

This thesis is the first attempt I know to synthesize these diverse elements into some cohesive pattern while raising questions about the nature of green building. As I will discuss later, extended producer responsibility (EPR) based on a life-cycle approach is the key to creating an ecological service-based economy. But EPR is ultimately a principle that is expressed very differently in manufacturing, in agriculture and in construction—and in different communities or sectors of the industry. It must also be expressed in regulatory modes that go beyond state command-and-control and are deeply embedded in a multitude of relationships between producers, suppliers, financiers, communities, consumers, retailers, and more. Changing forms of regulation are as much a topic of this dissertation as changing modes of production and construction.

This thesis is an attempt therefore to suggest a vision and contribute to the theory of green building and to the newly emerging field of construction ecology. It attempts to survey what I feel to be key areas and initiatives in green building, manufacturing and regulation; and to examine its relationship of all this to green community economic development and green economics in general. This has, like my first book, both a theoretical purpose, but also a practical one of how to implement sustainable practices in building and the economy.

An important sub-theme that I feel has great implications for education and strategy is the role of information and knowledge in the transition to a sustainable society. The nature of ecological production is knowledge-intensive. Information about building materials, about green production, about community needs, and about natural process is central in a transition to sustainability. Our values are very connected to our knowledge of the world we live in, and our knowledge of possibilities and potentials. Chapter II will begin therefore with this relationship to the fore, looking at the evaluation of building materials, and all that that entails. Then we can begin to look closer at production, consumption, recycling and regulation of materials.

CHAPTER II: EVALUATION
THE VALUE REVOLUTION:
INFORMATION & SERVICE IN THE BUILDING INDUSTRY

> "[If it is to be achieved, the new economic system] will result from our becoming better ecological accountants at the community level. If we must as a future necessity recycle essentially all materials and run on sunlight, then our future will depend on accounting as the most important and interesting discipline."
>
> --Wes Jackson, *Becoming Native to This Place*

The industrial economy's crisis of sustainability is ultimately a question of value. Ethics are part of this, but the crisis of value goes beyond subjective preferences to forces built right into the structure of industrial capitalism that drive the accumulation process. The postindustrial notion of an ecological service economy poses a challenge to the current system's accumulationist values. In this chapter I will look at the new forms of valuation in the building industry that have arisen to compensate for the growing inability of money to reflect real qualitative wealth. They are, as Wes Jackson suggests, forms of accounting, but a new kind of accounting of qualitative value, combining quantitative measurement with social and ecological priorities. They are means of answering the question "what is a green material?", and in doing so clarify the role of building materials in a construction industry geared to service.

While this chapter is focusing on the *content* of this value—expressed in concepts like Extended Producer Responsibility (EPR) and life-cycle analysis (LCA), it is impossible to overlook the *process* of its emergence and the various groups involved with developing it: green designers, eco-labelling and certification groups, publishers of green product guides, environmental and health activists, green marketers, academic researchers, government researchers and organizers, etc.

Quality, Information and Design

As discussed in the previous chapter, industrial capitalism is a system of quantitative development, and yet the emerging postindustrial productive forces are those geared to creating qualitative wealth. In the building industry, the conflict between quantity and quality is often quite conspicuous. The construction of more and bigger buildings, infrastructure projects and the like is often a major source not just of environmental destruction, but of the dehumanization of public space. It is no accident that a great number of the most positive contributions to green economics today have come from designers of buildings, landscapes and communities: people like John Todd, William McDonough, John T. Lyle, Jane Jacobs, William Rees, Pliny Fisk, Bill Mollison, and Stuart Hill.

This is mainly because the production of quality is largely a question of design. For these innovators it has been a short step from design of the built environment to design of the economy. The prominence of spatial designers is, however, also because they are people who are more intrinsically immersed in the "use-value", or material, side of economics, rather than the monetary or exchange-value side that preoccupies professional economists. Monetary budgets are important to designers, but saving money is usually a function of how well a design can make the most elegant and efficient use of materials and energy in meeting its intended needs. As industrial ecologists like Walter

Stahel have emphasized, postindustrial efficiency is far more about organizational factors and a careful consideration of end-use.

The production of quality and the production of service are, in practice, virtually the same thing. They demand the creation of the closed-loop "lake economy" described in Chapter I, but they also require, and are made possible by, a transformation in the role of culture in the economy, which is the root of the information revolution. Qualitative value is specific to context—in contrast to quantitative value (like the dollar) that is homogeneous and abstract. Qualitative value requires lots of knowledge about context.

Ironically, quality (i.e. regenerative wealth) also entails much more quantitative knowledge than does accumulation. Similarly, "post-materialist" value requires far greater awareness about material factors and flows than the old productivist industrial economy ever did. This is particularly obvious in building where life-cycle assessment and other forms of environmental impact evaluation are becoming commonplace. Targeting end-use, creating organizational efficiencies, moving with natural flows, and understanding the multi-dimensional impacts of our activities demands substantially more information than does simple financial payback.

Extended Producer Responsibility

For materials, the single most important principle underlying the ecological value revolution is extended producer responsibility, or EPR. EPR is not just an ethic, technique or mechanism, but a *relationship* that must be applied—often in quite different ways—to all sectors of the economy. It is a means of connection to the world around us, largely because it focuses on production systems rather than production facilities. The goal is to establish appropriate levels of responsibility for resources throughout a product's entire lifetime—for investors, distributors, developers, users and (especially) producers. It means much more than recycling, however, since it tries to incorporate this responsibility for the long-term costs and effects of producer decisions right into the design stage of products and services. For producing companies, EPR encourages them to look not only at what and how they produce, but also at their entire supply chain to make sure that their suppliers, product distributors and users are environmentally responsible.

In order to appeal to corporate producers, EPR is being promoted as a voluntary ethic by governments and green business consultants. The most well-known cases are found in industries like electronics and carpeting where a corporate culture is emerging that is supporting recycling and reuse. Xerox now focuses on selling document services rather machines, which it now leases. Maintaining ownership of the machines facilitates better maintenance and conservation, allowing Xerox to design the machines for easy disassembly and the reuse of functional parts. Interface, like other companies in the carpeting industry, are leasing flooring surfaces and designing their products to easily repair, recycle and reuse.

This is an important development, but not necessarily one that can be easily generalized to all other industries without state involvement. Most of the structural incentives and disincentives of the modern economy currently work against this ethic. EPR—and the life-cycle approach behind it—must also be built into the formal regulatory systems of advanced economies. Only by creating appropriate incentive and liability structures can the playing field be sufficiently levelled for regenerative production that increasingly mimics the closed-loop organization of nature's economy. A life-cycle-based economy ultimately must develop ownership patterns that encourage stewardship, and these tend to focus on use or service rather than property per se.

Some obvious examples of state-led EPR do exist. In the case of packaging, nations like Germany—with its "Green Dot" programme—have employed EPR "take-back" legislation to reduce its waste stream substantially (Fishbein, 1994). In North America, the most familiar—and modest—form of EPR is the beverage container deposit/return program which was the norm decades ago and is now making a comeback due to environmental movement pressure.

In Europe we are also finding an effort to coordinate various regulatory and market-based economic instruments in both national "environmental product policy" (or EPP), and the European Union's "integrated product policy" (or IPP) (Charter, Young, Kielkiewicz-Young, & Belmane, 2001). IPP is a set of policy instruments intended to stimulate green markets with coordinated initiatives on both the supply (product development) and demand (consumption) sides. Despite its corporate slant, its focus on "front-of-pipe" design solutions gives IPP promise as a transition to more comprehensive forms of stewardship.

What is most significant, however, is the beginning of an apparent breakdown of many of the abstract boundaries between private and public, voluntary and mandatory. New de facto forms of regulation are emerging from civil society and from industries themselves which are every bit as mandatory as state law, but are expressed in various forms of certification and green market creation that build alternative value into everyday enterprise. We will begin to consider some of these systems, or elements of these systems, in this chapter, including wood certification and green building assessment systems. In chapter VII on regulation I will look more closely at this important trend of postindustrial regulation.

EPR should be seen as a principle or relationship, especially in the building industry where simple "take-back" legislation would not be appropriate for all materials. It might work for carpeting, but different kinds of incentives would be necessary for lumber or roofing or other materials. In many cases, whole assemblies (floors, walls, etc.) or even whole buildings might be the more appropriate focus to create the economic loops that both mimic and harmonize with nature.

For EPR in the building industry, there are four key levels that should be considered: the *economy*; the *community*; the *building*; and the *product or material*. My particular focus will be on the last two—the building and the material—but none of these areas can be completed separated. For example, selection of specific materials has intrinsic connections to the community, bioregion and larger economy simply because efficiency requires making the most of local resources and minimizing unnecessary transportation costs. In this thesis, for practical reasons, I will not attempt to deal with many questions of planning and urban design that can so influence materials use. But because system dynamics and green markets must be considered, I will bring in some key questions of community in later chapters.

While it has been essential to introduce the concept of EPR at this point in the thesis, the concern of this chapter is not primarily about EPR, but about the information and valuation behind EPR. As we will see, such knowledge—if properly utilized—can become a regulatory force in itself. In subsequent chapters, I will return to how EPR relationships can actually be created (and are actually being created) through action by government, firms and the community.

The Life-Cycle Approach

The most important information necessary to design EPR relationships is that derived from what has been called a life-cycle approach. It is an attitude and mode of thinking that is expressed in a range of environmental assessment tools, certification systems, labelling programs, directories and databases, and green design initiatives. It is a mentality of valuation that attempts to understand the effects of a product or process "from cradle to grave". In the words of Dave Wann (1996, p. 32), it "responds to the quintessential question, where does [a product or substance] come from, what does it accomplish, and where is it going?" While the concept is simple, this understanding does not come easily, since economic activities are in fact a complex web of relationships. It is not simply a matter of tracing a linear path from material extraction, to processing and manufacturing, to distribution, to installation and use, to disposal. All along the way there are inputs and outputs that must be considered—for example, in the "use" stage of building material, the cleaning substances used and the outgassing of chemical constituents. Those substances and constituents themselves likely have multiple impacts. And every kind input or output is different, with a greater or lesser importance in the overall scheme of thing.

The life-cycle approach can also be applied to social factors. All along the life-cycle, products and materials create (or eliminate) certain kinds of work; create certain kinds of social, sexual, and organizational relationships; and have specific kinds of economic or quality-of-life impacts. As we will see later, technical tools are being developed that can quantify or at least account for many of these non-environmental impacts. There are also systems of indicators, like sustainable community indicators, which can combine the results of environmental life-cycle analysis with other indicators of health, quality of life, prosperity and social equality. The possibilities are endless, but underlying it all is a search for qualitative values that can help regenerate communities and ecosystems.

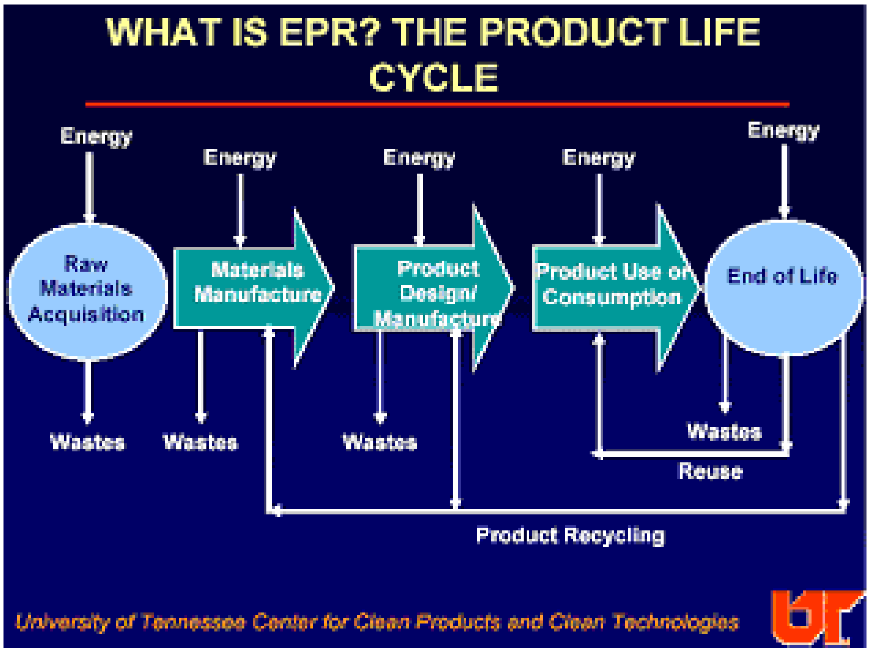


Figure 3. Overview of EPR
Source: Davis, 2002

Forms and Criteria of Evaluation: What is a Green Material?

The most general criteria with which to evaluate building materials are three: resources, pollution and performance (Berge, 2000). The ***resources*** used by a material include all the materials and energy used to extract, process, use and dispose of it. The energy used to produce it, known as embodied (or embedded) energy can be particularly large for building materials. For a building as a whole, the amount of embodied energy can equal the amount of energy it takes to run the building for anywhere from seven to twenty years, even in our harsh Canadian climate (Trusty & Meil, 1999).

Pollution includes all the emissions of the mines and factories used to produce the material, as well as the emissions of use—formaldehyde outgassing, and emissions from products used to clean and maintain the material—along with the pollution resulting from its final incineration or landfilling.

Performance refers to how well the material does its intended job. Materials with low durability, no matter how benignly produced, can hardly qualify as green. For materials like insulation and windows, performance goes beyond durability, since good thermal performance, for example, can actively save resources and energy.

These three categories certainly overlap, as for example the performance of a window or roofing material may influence the resources and energy they use.

To really appreciate how these criteria—along with the general priorities for dematerialization and detoxification—apply to building materials, it is important to understand the distinctiveness of materials in construction. Perhaps the most important thing about building materials is that, because they are much longer-lived than most materials, they have a ***"use-dominated"*** life cycle. This tends to make durability and performance somewhat more important than for many other kinds of products.

The following list—adapted from Nadev Malin (1999), one of the US's main experts on building materials—constitutes a very rough prioritization of evaluation for building materials. Note that the use phase comes first because of its importance, followed by manufacturing, extraction and disposal:

Construction and Use phase

1. energy use: How will this material affect energy use?
2. occupant health: How will it impact occupant health?
3. durability: How durable will it be in this application?

Manufacturing Phase

4. hazardous by-products: Are toxic or hazardous by-products created during manufacture?
5. energy intensity: How energy-intensive is the manufacturing process?
6. process waste: How much solid waste is generated during manufacture?

Raw Materials Phase

7. resource limitation: Is this material produced from a limited or endangered resource?
8. resource extraction: Does harvesting or mining the raw materials cause ecological harm?
9. transportation: does shipping of raw materials use excessive energy?

Disposal or Reuse Phase

10. recyclability: Can the material be easily recycled at the end of its useful life?
11. hazardous demolition: Might the material become a hazardous waste problem at the end of its useful life?

Summary

12. What other concerns, specific to the product in question, has this process missed?

While these simple questions provide a fair overview of the environmental concerns around materials, the specifics for every product or product category might be quite different. A quarried material, for example, would require a much greater concern with the raw materials phase than the manufacturing phase. And some products—e.g. asphalt shingles that constitute big problems for municipal landfills, or toxic items like arsenic-treated wood—would require higher priority concern for the disposal phase. It is also interesting to note that, while most experts agree that the long life of building materials is an important fact, in recent years increasing attention is being paid to the embodied energy, resource and pollution impacts of building materials. As new LCA data emerges, the impact of building materials "upstream" (in extraction and processing) is being recognized as much greater than experts previously believed (Trusty & Meil, 1999).

As we will see, the evaluation of materials can be quite complicated. The very priority of use and performance for a building material means that it is often not an obvious matter of comparing one material to another. Environmental impacts depend very much on how the materials are used. It might be more sensible to compare, for example, one wall assembly with another wall assembly (or even one building with another building), rather than simply the components within them.

Closely related to this is the difficulty of achieving ***functional equivalence*** when comparing alternatives. All evaluation systems are systems of comparison. Those with the greatest claim to objectivity are also systems of quantification. Choosing the most appropriate units of comparison is essential. For example, it would not make sense to choose between ceramic and vinyl floor tiles by comparing their relative environmental impacts *per pound or kilogram*. One would have to use something like impacts *per square metre of flooring*. In fact, in most cases, it would be better to consider the whole flooring assembly per metre, since the adhesives and underlayment required for each product could have major impacts. In comparing building materials it is often very difficult to avoid comparing "apples and oranges" in order to determine the most appropriate measures of functional equivalence.

How comparisons are made also depend on the overall goals and audiences of the evaluation systems. All systems—however simple or complex—are usually some combination of evaluation and encouragement. They are all intended to create conditions for improvement. No evaluation system, no matter how scientifically based, is absolutely objective; some advocacy is implicit. But all systems express a different mix of evaluation and encouragement. Whereas life-cycle assessment (or LCA) is a more formalized quantitative procedure, eco-labelling and green product directories are more explicitly concerned with promoting the use of environmentally-benign products to consumers. But the subjective and objective elements of encouragement and evaluation are involved in all these systems.

The different audiences affect the level of simplicity and aggregation in the systems (Jonsson, 2000). Some evaluation tools are software programmes for LCA specialists; they do much less interpretation and aggregation, and more raw data processing. Other evaluation tools are services for decision-makers. For example, the results of Holland's EPM ranking system, and many other forms of life-cycle assessment, are intended for use by manufacturers, designers or policy-makers, in order to improve their product or select the most ecological material for their project. Another more simplified system is eco-labelling—like Canada's EcoLogo, the US Green Seal, or the EU Flower (figure 4)—which is intended for public education and green marketing. For this reason, although they may be based on sophisticated life-cycle analysis, the results must be much more aggregated and simplified, more easily understandable to non-specialist audiences.

Figure 4. EU Flower Eco-logo

As noted above, all evaluation systems are oriented to some kind of comparison—even as they seek some understanding of a material's objective impact on the environment (or economy, or community). This might be a comparison between specific products, or between certain kinds of products, or just between a product and its own particular impact.

Any or all of these comparisons can be useful, depending on the purpose and audience for the evaluation. The point is that value must be expressed in different forms, for different people, at different stages of the economic life-cycle. While some forms of evaluation may be competing, using different methodologies for the same purpose, in many cases these evaluation systems are complementary and non-exclusive, making the best use of knowledge for the purpose of transforming some level of production or consumption.

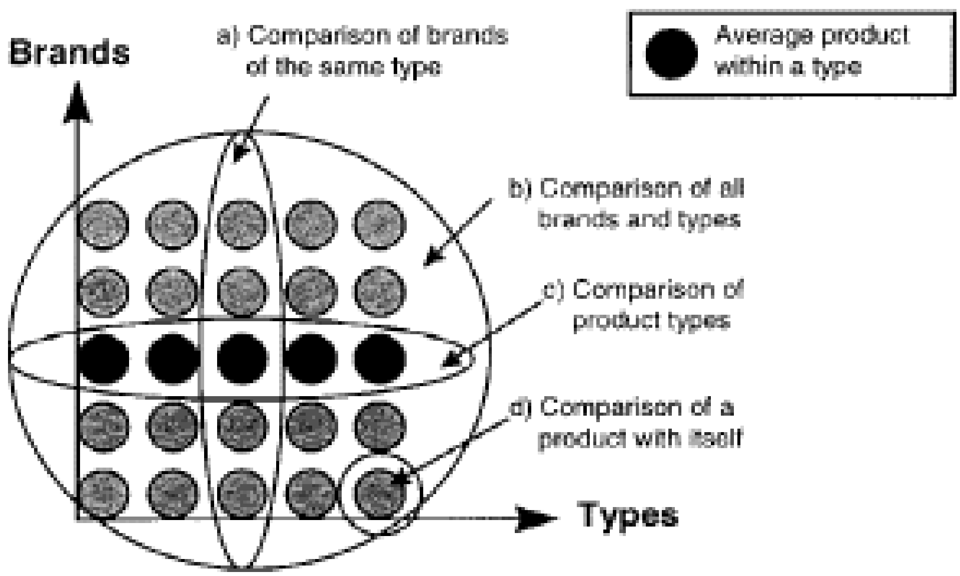


Figure 5. Relevant Comparisons in Environmental Impacts of Building Products
Source: Jonsson, 2000

Life-Cycle Assessment: the Holy Grail of Green Building

It makes sense to begin any detailed discussion of evaluation systems with life-cycle assessment (LCA) because it is the most technical and comes closest to an "objective" scientific quantification of environmental impact. In this sense, it is considered the Holy Grail of green design, be it in building or manufacturing. It also supplies much of the scientific basis for other forms of evaluation, certification and labelling. LCA systematically tries to quantify all the resources used, and the releases emitted to the environment, through every stage of a product's life cycle—with the goal of making improvements that will reduce these impacts.

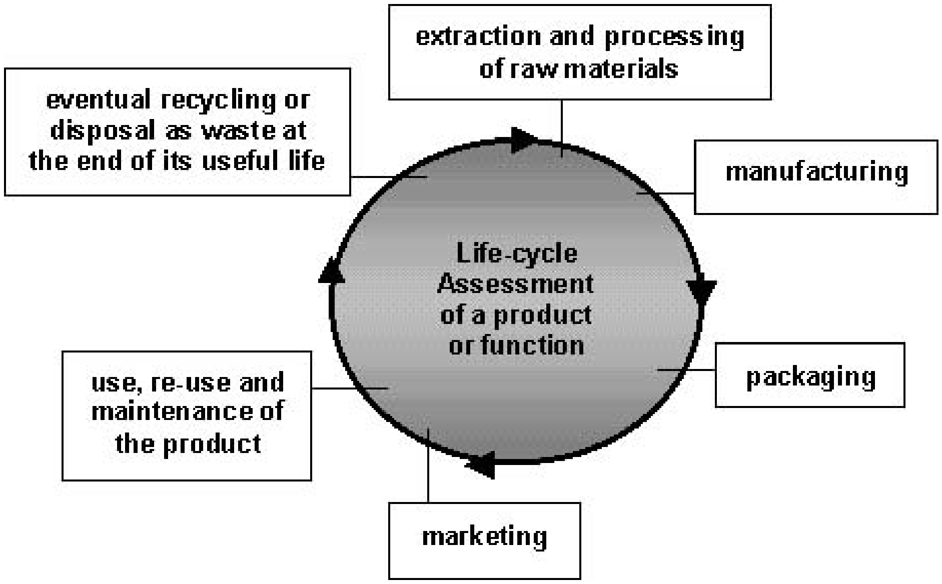


Figure 6. LCA in Context
Source: UNEP, 2004

LCA originated in the late sixties with defensive corporate concerns about specific products. Reportedly, the first instance was Coca-Cola's efforts to determine the environmental impact of switching from glass to plastic bottles (Malin, 2002). In the seventies, concerns with energy led to energy and environmental profiling; and although there was little public interest in LCA in the eighties, researchers in the new field made progress in their refining methods. The nineties saw an explosion of interest in LCA, by academic, environmental, corporate and governmental bodies.

Coordinating and catalyzing action internationally has been SETAC—the Society of Environmental Toxicology and Chemistry. Although numerous other organizations and individuals have been involved, SETAC is the international body that has been most responsible for carrying out research, developing standards and generalizing LCA. Its work has increased the status of LCA as an essential part of environmental management, and as a result, procedures for various kinds of LCA are now being standardized by the International Standards Organization (ISO) though the 14040 series in tandem with the ISO 14000 series of environmental management standards (Environment Canada, 1998).

LCA is being widely used and carried out by firms, universities, and governments for design, management and regulatory purposes. In addition to their concerns to conform to new environmental management standards, ***private firms*** are using LCA to access potential liability issues. ***Governments*** are using LCA as an extension of traditional environmental impact assessment in order to create new forms of extended producer responsibility (EPR) rules. They are helping coordinate the development of LCA procedures that can catch on more quickly with the building industry. They are also using LCA to guide green procurement policies, since the state is a major consumer of materials. ***NGOs***, like women's health, labour and environmental groups, are also sponsoring and using LCA studies to create positive pressure for change, usually in collaboration with progressive academics and university institutes. Finally, as noted above, LCA provides a scientific basis for various kinds of design, labelling and certification initiatives, which can be private, governmental, or community based, or more commonly, a combination of various stakeholders from these sectors.

When considering the range of LCA tools in building, it is important not just to make a distinction between LCA geared to individual products, and systems geared to assemblies or whole buildings. Figure 7 for example highlights the life cycle inventory stage from the perspective of a building as a whole:

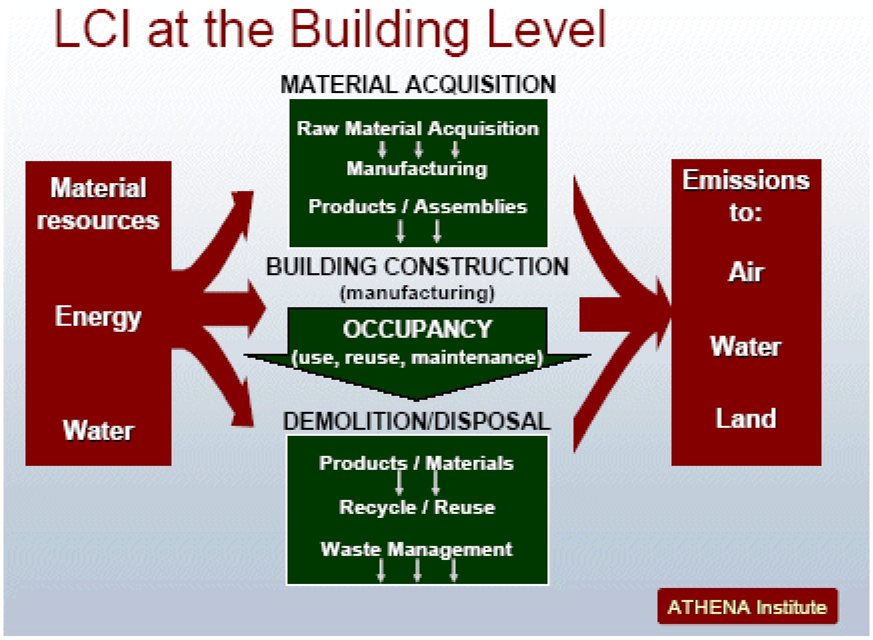


Figure 7. Building Life Cycle Inventory
Source: ATHENA S.M.I., 2004

It is important to also distinguish between LCA systems designed for LCA practitioners, and those intended for other kinds of professionals who need LCA, like architects, builders and developers. The former tools—like the Dutch SimaPro, French TEAM and Swedish SPINE software—do not simplify and aggregate information like tools meant for part-time practitioners or designers—like the U.S. BEES (Building for Environmental and Economic Sustainability), Britain's ENVEST or the Canadian ATHENA software tools.

There are different kinds of LCA, but the most significant distinction is between micro- and macro-scale LCA. The latter, also known as "process LCA" moves upward and outward from the specific product or process, along the supply chain upstream, during the production process, and downstream through distribution, use and disposal. Macro-scale LCA, also known as "economic input-output LCA", begins with statistics for whole sectors of the economy. I will review some examples of these in the next section, but this section will focus on conventional process LCA, in which there are four main steps:

1. scoping or goal-setting.
2. life-cycle inventory (or LCI): fact-finding to identify and quantify all relevant inputs (e.g. water, energy, and resources), and outputs (including discharges to air, water and land) over a product's entire life time.
3. life-cycle impact assessment (or LCIA): analysis of the inputs and outputs described above, often classified in terms of environment, human health, energy use and building operation.
4. improvement analysis: identifying opportunities for improving life-cycle performance. (Young and Vanderburg, 1994; AIA/Demkin, 1998)

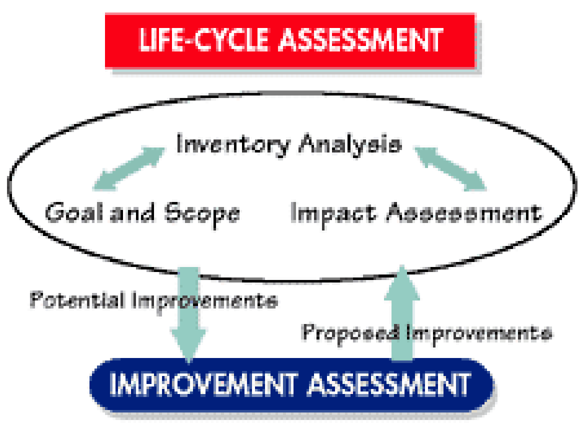


Figure 8. LCAIA
Source: EBN, vol. 11, no. 3

Objectivity and Purpose

While LCA does carry an aura of objectivity, there is in fact a large measure of subjectivity to it. This is not just because of the very "bias" of LCA in selecting certain impact categories, but also because of the complexity of the interrelationships involved. This complexity requires LCA practitioners to apply simplifying assumptions at each stage. Various international organizations, like SETAC and ISO mentioned above, are constantly trying to standardize these assumptions in order to bring some uniformity and comparability into assessment. At the same time, new software tools are being developed to provide needed data for the assessment. Nevertheless, material selection remains almost as much an art as a science.

The complexity of comprehensive LCA has also held back its practical use by industry, contractors, designers and consumers. This has spawned initiatives to simplify or "streamline" it to allow it to be applied more widely. There has been some negative reaction to this by those who fear oversimplification, but other researchers (J. A. Todd & Curran, 1999) have argued that streamlining is part of any LCA. There is a growing recognition that "full-scale" and "streamlined" LCA are not so much two separate things, but a continuum along which many appropriate forms of LCA can exist. Proponents of this viewpoint argue that the bigger problem is that few protocols have been developed to guide the process of simplifying, particularly at the "***scope and goal***" stage, without compromising the integrity of the study.

Subjectivity is a factor even in the most "objective" part of an LCA, the second or ***inventory*** (LCI) stage where decisions are made about the key input and output accounts. Depending on the product, there is some leeway in the very choice of accounts. In addition, there are so many estimates and assumptions in the data collection that, according to Nadev Malin (2002, p.10), “unless the same researchers are studying the different products, it is nearly impossible to ensure that the inventories of inputs and outputs were compiled in a consistent manner.”

In the third or ***impact assessment*** (LCIA) stage, there is a particularly large measure of subjective involvement, both in the selection of the categories and in the weighting of categories according to their importance. Examples of impact categories are global warming, indoor air quality, acidification and toxicity (table 1). The categories employed by different national green building programs, for example, might feature attributes dictated by their ecological situation. Whereas Europeans might highlight a product’s contribution to acid rain, an Australian system might be more concerned with ozone depletion, and Africans more concerned with resource inputs (Berge, 2000). The impact categories selected may, however, simply have to do with the perspectives of the LCA designers. In the Australian LCAid system, for example, impact categories include “carcinogenesis”, “heavy metals” and “pesticides”, whereas the US BEES system uses the categories “ecological toxicity”, “human toxicity” and “indoor air quality”. Many of the programs for both products and for buildings allow program users to change the weightings in comparing materials for their specific projects. For example, the BEES program allows users (usually building designers) to adjust the ratio of environmental, health and financial factors.

Impact Category	Scale	Relevant LCI Data (i.e., classification)	Common Characterization Factor	Description of Characterization Factor
Global Warming	Global	Carbon Dioxide (CO_2) Nitrogen Dioxide (NO_2) Methane (CH_4) Chlorofluorocarbons (CFCs) Hydrochlorofluorocarbons (HCFCs) Methyl Bromide (CH_3Br)	Global Warming Potential	Converts LCI data to carbon dioxide (CO_2) equivalents Note: global warming potentials can be 50, 100, or 500 year potentials.
Stratospheric Ozone Depletion	Global	Chlorofluorocarbons (CFCs) Hydrochlorofluorocarbons (HCFCs) Halons Methyl Bromide (CH_3Br)	Ozone Depleting Potential	Converts LCI data to trichlorofluoromethane (CFC-11) equivalents.
Acidification	Regional Local	Sulfur Oxides (SOx) Nitrogen Oxides (Nox) Hydrochloric Acid (HCL) Hydroflouric Acid (HF) Ammonia (NH_4)	Acidification Potential	Converts LCI data to hydrogen (H+) ion equivalents.
Eutrophication	Local	Phosphate (PO_4) Nitrogen Oxide (NO) Nitrogen Dioxide (NO_2) Nitrates Ammonia (NH_4)	Eutrophication Potential	Converts LCI data to phosphate (PO_4) equivalents.
Photochemical Smog	Local	Non-methane hydrocarbon (NMHC)	Photochemical Oxident Creation Potential	Converts LCI data to ethane (C_2H_6) equivalents.
Terrestrial Toxicity	Local	Toxic chemicals with a reported lethal concentration to rodents	LC_{50}	Converts LC_{50} data to equivalents.
Aquatic Toxicity	Local	Toxic chemicals with a reported lethal concentration to fish	LC_{50}	Converts LC_{50} data to equivalents.
Human Health	Global Regional Local	Total releases to air, water, and soil.	LC_{50}	Converts LC_{50} data to equivalents.
Resource Depletion	Global Regional Local	Quantity of minerals used Quantity of fossil fuels used	Resource Depletion Potential	Converts LCI data to a ratio of quantity of resource used versus quantity of resource left in reserve.
Land Use	Global Regional Local	Quantity disposed of in a landfill	Solid Waste	Converts mass of solid waste into volume using an estimated density.

Table 1. Commonly Used Life Cycle Assessment Impact Categories
Source: US EPA & Science Applications International Corporation

LCA Challenges

As a young discipline, LCA faces many difficulties. There are problems with the amount and quality of data, problems in determining and weighting impact categories, and problems with generalizing LCA and making it practically relevant to those who should be using it. I have touched on some of these problems above: for example, the difficulty in establishing functional equivalence in comparing alternative materials and systems.

Many discussions of LCA want to focus on the impact assessment stage, but probably the biggest challenges lay in the realm of the inventory, and the collection of raw data. This is crucial since “garbage-in equals garbage-out”. Different LCA tools use different sources. Some come from manufacturers, others from national averages derived from government estimates. Others use regional averages. When exact data is missing, assumptions have to be made—for example, in the transport distance between the mining and processing of certain ores. The lack of standardization of data sources presents real difficulties for users, and undermines the credibility of LCA in general.

Another challenge in LCA is double-counting or the allocation of impacts. A window’s environmental impact might be attributed to the window, the heating system, or a power plant. And when a company makes multiple products in the same process, resource and pollution flows have to be allocated among the products. Standards for LCA, such as those being developed through ISO, are trying to deal with these difficulties, but then practitioners and national organizations have to figure out how to apply these guidelines.

Most forms of LCA limit themselves to comparing generic product types rather than individual products. Obviously there can be a great difference between how different brands of lumber, or flooring, or insulation are produced. Designers probably want LCA data based on industry averages, but procurement officers and specification writers need information on specific products. BEES is one notable case of a life-cycle tool that is attempting to accumulate individual product data, and obviously there will be a growing need for this kind of analysis (Lippiatt, 2002).

There is an endemic problem in LCA with the contradiction between the need for detailed and accurate data on one hand, and capitalist competition on the other. Many companies are fearful of revealing proprietary information about their products and production processes. They do not want to give away “trade secrets” and a possible competitive advantage, but they are also fearful that an LCA may show that their products do not stack up well. Besides giving an edge to their competitors, it may also give ideological fodder to environmentalists and regulators who want to clean up company practices.

Nevertheless, there are major efforts afoot to increase the amount of reliable data. BEES has a reasonably successful “BEES Please” program to entice manufacturers to provide data. And the US government is behind a major effort, organized through the National Renewable Energy Laboratory (NREL) and coordinated by the Ontario-based ATHENA Sustainable Materials Institute, to produce a national public life-cycle inventory (LCI) database, and help provide regional benchmarks for various products and processes (ATHENA Sustainable Materials Institute, 2004).

Besides all these challenges to secure appropriate data, there are also difficulties in the actual assessment stage. First are the choices of impact categories—acidification, global warming, etc.—but then are the difficulties about how these categories generate numerical results. Global warming impact, for example, demands that a number of different kinds of gases are translated into CO2 equivalents. An impact category like “ecosystem toxicity” must also be reduced to some significant indicators or collection of emissions. In many cases, a time factor must be considered, because emissions over a short or a long time frame may have very different impacts. For many kinds of impact assessment categories, collections of indicators must be employed to synthesize an overall impact. And this may be done quite differently in one system or another.

The assumptions that must be made both in filling in gaps in data, and in assessing the data for environmental impacts, suggest another difficulty with various LCA tools: their *transparency*. That is, whenever certain assumptions must be made, it is desirable that these assumptions be *visible* (or at least accessible) to those who need to know how results were arrived at. In some LCA tools, these assumptions are not made explicit to the user. This is especially important when the results of two different LCAs on a particular product come to different conclusions. Of course, this question of transparency is usually more important in LCA tools intended for use by LCA practitioners than those tools intended for designers and policy-makers which must aggregate and simplify more.

Another problem of most product-based LCA systems is the assumptions that they must often make about the ***use*** of a material. In many LCA systems, the use phase is the area of most uncertainty. This is partly because the impacts involved are so specific to the building and situation. Obviously this is a big deal for building materials—which have such a long use period. The problem is a bit different for individual products, for building assemblies, and for whole buildings—and thus the solutions can be quite different. For buildings, operating energy is the biggest factor. But for individual products, cleaning and maintenance—which may generate substantial emissions—may be bigger considerations. Does a flooring product, for example, require frequent cleaning? What kind of cleaners must be used? The indoor air quality (IAQ) impact of maintenance may be far greater than some products' production impact, especially with such a long-life product.

The final challenge to LCA is, of course, generalizing its use throughout the building industry, including manufacturing. Solving the problems discussed above will help, but conversely increasing the popularity of LCA will help solve those problems. LCA is not something that the non-specialist can do. However, it is not something that the average designer, manager or regulator would want to do. What is needed are intermediary tools that make the results of LCA studies available in practical forms that can be easily used. The explosion of life-cycle awareness in the last decade has in fact resulted in the emergence of just these kinds of tools—for use by architects, engineers, product designers, managers, etc. Some of these are programs, like BEES, that designers can download (sometimes for free) from the Internet and then use to plug in numbers and weightings for their particular projects. Others are directories or guides that designers can review before making material choices. The Environmental Resource Guide, which was published by the American Institute of Architects (AIA) between 1992 and 1999, combined quantitative with qualitative analysis of key product areas, along with case studies of specific buildings (Demkin, 1998). LCA is also being applied to building assemblies and whole buildings (through design tools that I will cover later in this chapter). The widespread use of LCA by designers, however, probably depends on the functional integration of LCA information into computer-aided design (CAD) and drafting tools (Levin, 2000).

Despite rapid progress in recent years, there is much work that needs to be done with both LCA systems, and with intermediary tools using the life-cycle approach. While it is probably true that one single standard kind of LCA would not be appropriate, many of the existing differences in LCI data sets and LCIA impact categories are needlessly incomparable, making for confusion and impracticality. In such a young field, this is understandable and there is a substantial amount of consultation to overcome these problems. Europe is several steps ahead of North America in this regard. But the US Dept. of Housing & Urban Development (HUD) in April, 2001 convened a workshop/think tank of the top experts on LCA in building to consider the state of the art, and chart directions for the field that could practically impact on the housing industry in the U.S. (National Association of Home Builders (NAHB) Research Center, 2001a). It is planning similar sessions to be held periodically. Coupled with projects like the NREL US LCI Database project mentioned above, LCA activity should continue to grow in both quality and practicality.

A particularly interesting initiative in this regard is a grassroots effort based in Portland Oregon called the *Sustainable Products Purchasers Coalition* (SPPC). It combines expertise in LCA with grassroots membership. Besides helping to develop consistent standards for LCA studies and encouraging firms to engage in LCA, it tries to demonstrate to producers, through its membership, that there is a substantial market for products that meet the Coalition's life-cycle standards (Sustainable Products Purchasers Coalition (SPPC), 2002). It provides one of the best examples of the power of information (combined with vision and community organization) to create market power that in turn transforms production. I will return to this topic and discuss SPPC more thoroughly in Chapter VI.

Macro-Scale LCA

Conventional forms of LCA—"process LCA"—move from the specific details of production outward, up and down the supply chain to add up total environmental impact. There are, however, forms of LCA called "economic input-output LCA" that begin with macro statistics on flows in whole economic sectors, and proportionally deduce resource use and pollution for specific projects or products. The two most well-known examples are the *EIOLCA* software developed by the Green Design Initiative of Carnegie-Mellon University, and *Baseline Green*, developed by Austin's Maximum Potential Building Systems (Max's Pot), Sylvatica Consultants, and Kansas City's BNIM Architects.

The EIOLCA software is based on public data sets—from, for example, the US Dept. of Commerce and US Environmental Protection Agency (EPA). While it is not a satisfactory alternative to conventional process-based LCA for all purposes, it can give developers and investors a fair idea of the environmental impact of a specific chunk of investment in a particular sector. The model captures all the various manufacturing, transportation, mining and related requirements to produce a product or service. There are about 500 sectors in the EIOLCA model, with data sources on economic impacts, electricity use, fuel & ore use, fertilizer use, pollutant emissions, greenhouse gas emissions, toxic releases, external costs, water use, safety data and employment data (Hendrickson, Horvath, Joshi, & Lave, 1998).

Baseline Green, initially developed in 1996 with some funding from the U.S. EPA, specifically targets the construction industry, and is also based on public data sets. Its developers argue that while there can be over 500 upstream impacts from a single building, roughly two dozen impacts account for over 75 percent of total environmental impact. They emphasize that developers should target those particular impacts, and that Baseline Green helps do this (Norris, Fisk III, & McLennan, 2000). The program allows designers or builders to check for impacts at various stages in the design-build process. It groups the hundreds of building components within the familiar Uniformat II construction material specification categories. It runs the program for those inputs, and the results are used to identify which building system categories make the highest contributions to total upstream burden of the project, and which specific inputs within each category rank highest in terms of the environmental improvement leverage they provide.

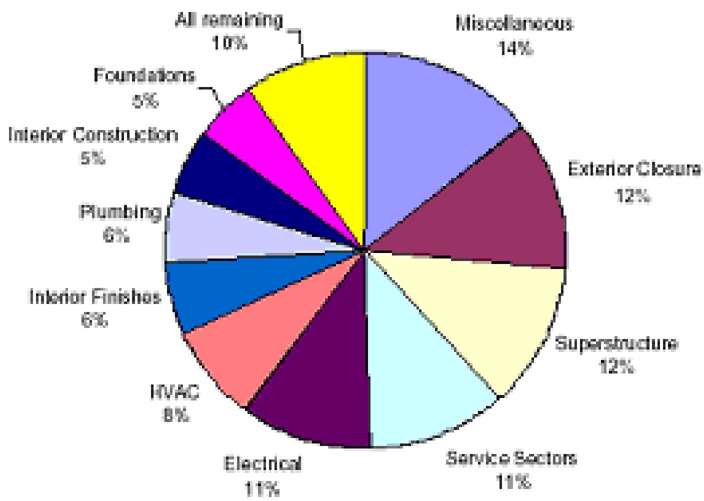


Figure 9. Baseline Green: Upstream air pollution shares of input categories:
Montana State University EpiCenter project designed by BNIM.
Note: A surprising aspect of the results is the relative importance of some of the less massive input categories, such as electrical, HVAC, and interior finishes.
Source: Norris, Fisk & McLennan, 2000

An unique feature of Baseline Green is of great interest to those concerned with bioregional community development. That is, for a given bill of materials on a project at any scale, the program can demonstrate the resulting impact to jobs created, wages earned, industrial output, and thus overall regional economic effects. The macro statistics on the existing economy, represented through geographical information systems (GIS), can project local employment and economic impacts, and enable developers to design their projects for optimal bioregional benefit (P. I. Fisk, 2002). Conventional process-oriented LCA contains no regional feedback mechanisms, aside from registering transportation costs.

Again, this kind of LCA would ideally supplement other kinds of LCA or design tools. Input-output LCA does not consider the use or disposal of a material, just its production impacts. Its reliability is dependent on the reliability of the government statistics it uses, and some environmental impacts, like habitat destruction, are not provided. Nevertheless, it is another example of a design tool that takes a novel approach to assessing the value of a building project, one that will undoubtedly grow in sophistication in the coming decade as more and better data becomes available.

Building Assessment & Certification Systems

As noted above, limiting evaluation to individual materials can be a problem since so much depends on how these materials are used and combined together. The emergence of environmental assessment systems for assemblies and for whole buildings is a logical evolution of both green building and industrial ecology.

The ATHENA Sustainable Materials Institute has developed a typology of assessment tools that has been well received by professionals in the area (Trusty, Meil, & Norris, 1998). It comprises three kinds of tools. Most in the "level 1" category—product assessment tools—were covered in previous sections. "Level 2" tools are whole building decision support tools that focus on a specific area of concern. They are software programmes or systems that calculate life-cycle environmental impacts, or operating energy, or life-cycle economic costs, or perhaps some simple combination of these things. They include the ATHENA design tool, the Dutch Eco-Quantum programme, the British ENVEST programme, and the US DOE2 programme. They usually involve some kind of weighting or scoring, and the results can contribute to "level 3" tools.

"Level 3" building assessment tools include the national building assessment systems—like the UK's BREEAM, the US's LEED and Norway's ECOPROFILE—along with international systems like the GBTool. They synthesize a whole range of issues that constitute an agreed-upon definition of sustainable or green. They combine objective and subjective data, oftentimes relying on the “level 2” tools for the objective data. Because subjective elements are important here, these systems do not literally constitute “life-cycle assessment”, but rather the application of a life-cycle approach. Nevertheless, as systems of life-cycle analysis continue to evolve and encompass greater complexity, the trend in building assessment should be to move closer to more objective LCA.

The first major—and the most influential—system of environmental building assessment was BREEAM, the British Research Establishment’s (BRE) Environmental Assessment Method that debuted in 1990. It categorized a variety of building types against a range of approximately 18 performance criteria organized in three scales: global, local and indoor. With the method mainly intended for the new office construction sector, BRE estimates that perhaps 30 percent of new office buildings in Britain since 1990 have received a BREEAM rating. Reflecting the political situation of Britain since Margaret Thatcher, its primary focus has been on using environmental performance as a way of increasing corporate benefits—through, for example, lower operating costs, improved work environment, and green marketing. It has been a model for many other national systems, like Hong Kong’s HK-BREEAM and BREEAM-Canada (Bartlett & Howard, 2000).

The continental European systems emerged in a different context where government regulation was a bigger factor. The “level 2” tool Eco-Quantum, for example, was an attempt to create a common language of environmental assessment and establish some standardization among various Dutch municipalities and within the building industry generally. Initiated around 1995, the first version of the programme was ready by 1997, and a polished version was introduced to the commercial market in 1999. It helped to establish Dutch building assessment in rigorous LCA, but quite differently than the ATHENA system, geared more for a market-driven context.

Beside the national systems geared to specific markets, the Green Building Challenge (GBC) has emerged internationally as a means for researchers and practitioners in building assessment to test systems and strategies. A consortium of over 30 countries, the GBC process was launched by Natural Resources Canada in 1996, but in the early years included mainly European members. Its main goal has been to advance the state-of-the-art in building environmental performance assessment methodologies, and to do this through periodic conferences, and the formulation of an internationally accepted generic framework. The framework would be used to compare existing building environmental assessment methods and to produce regionally based industry systems. The GBC has also served to showcase the performance assessments of environmentally progressive buildings. It has held conferences in 1998 (Vancouver), 2000 (Maastricht, the Netherlands) and 2002 (Oslo Norway). It has been growing rapidly, but its role has changed as more national systems have emerged. Its calculation tool—the GBTool—while not geared to a specific market is making contributions to the field of building assessment that can be used by future versions of national systems (J. A. Todd, Crawley, Geissler, & Lindsey, 2001).

In North America, the most significant development has been the emergence of the Leadership in Energy and Environmental Design (LEED) system. LEED is a self-assessment and the rating system developed by the US Green Building Council (USGBC). The Council was founded in 1993, but has in recent years exploded in membership. Less than twenty buildings were certified under LEED 1 before March 2000, and LEED 2 had certified just over 25 to Feb. 2003. But hundreds of buildings have been registered in the program since 2001, and LEED's sudden popularity seems to be changing the face of mainstream commercial building in the US. In 2002, LEED certified buildings accounted for almost 5 percent by floor area of new commercial construction in the US. Newly registered projects include numerous federal government and even US military structures, and the ranks of green building professionals, previously a small group of committed activists, are being swelled by a new wave of LEED-certified architects and engineers in mainstream firms. LEED seems also to be changing the Canadian construction industry, as initiatives are being undertaken to implement LEED or LEED-compatible assessment systems here (Trusty & ATHENA Sustainable Materials Institute, 2002). Previously the UK's BREEAM had been a bigger influence on building assessment in Canada.

LEED like BREEAM is market-oriented and voluntary, but in structure is quite different. BREEAM, like the assessment framework of the Green Building Challenge, is more of a pure assessment system—with an emphasis on tabulating environmental loadings. The LEED system is more of a design-support tool, based on a checklist in five key areas—sustainable sites; energy and atmosphere; water use; materials and resources; and indoor environmental quality. There are weighted credits for each area, but the developer has a choice as to what areas to seek credit for. Buildings get ratings—from highest to lowest—of platinum, gold, silver, bronze, and basic-certified, depending on how many credits they accumulate; but this is more an incentive system than a measure of environmental impact.

Modern credit-systems like LEED do a good job of expressing a life-cycle spirit, but in some crucial areas, they fall short of reflecting a building's objective environmental impact. This is particularly in the area of materials selection. As the ATHENA Institute's Trusty and Horst (2002, p. 2) write,

> [An] example is the LEED credit for the use of rapidly renewable materials. The stated intent of that credit is to, 'reduce the use and depletion of finite raw, and long cycle renewable materials by replacing them with rapidly renewable materials.' Rapidly renewable is defined as a rotation period of less than 10 years. Among a number of problems with a credit like this, is the fact that it ignores the value of land as a finite resource as well as the implications of all of the fertilizers, pesticides, insecticides, etc., that may be used in the process of producing rapidly renewable materials. Nor is there any a priori scientific reason for preferring a short cycle renewable over a long cycle renewable, let alone an arbitrary 10 year rotation over a 12, 15 or 20 year rotation.

Trusty's solution is a better integration of rigorous LCA tools (that can more systematically account for full impacts) within the accreditation system—primarily through the use of the 'level 2' tools like ATHENA's and Eco-Quantum. But this depends, in turn, on the broadening of these tools applications and an improvement in raw data quality in many regions. And it also requires a seamless integration of the calculation tools into the certification process.

Doing this is easier said than done for many of the reasons discussed in previous sections: gaps in data, assumptions required, determining functional equivalence, etc. LCA is complex, but LCA for buildings involves multiple complexities. The difficulty of establishing functional equivalence is especially problematic for buildings. Not only does a designer have to consider comparability in terms of loads, spans, space enclosure and surface coverage in comparing building assemblies or products, but he/she must also take into account all their relevant properties and relationships over the building's life. For example, concrete and steel have very different thermal mass and conductivity, and so could have quite different implications for building energy use. Systems that have equal load-bearing capacities might have very different weights, and the heavier system might require substantially larger footings and foundation. The extra materials would increase the embodied energy of the structure, and thus total environmental impacts (Trusty & Meil, 1999). As Wayne Trusty points out (Malin, 2002, p.15), “The real functional unit is a piece of space to fill a certain need. That’s the level which we should ultimately compare.”

One important challenge for green building assessment is the need to move beyond the commercial and multi-residential sectors, and especially beyond new construction. The focus of most building assessment systems has been new commercial and high-rise construction. But most of the building stock that will exist in 30-50 years exists right now, and the greening of the built environment depends very much on upgrading the existing buildings. A few systems, like the Green Globes adaptation of BREEAM, backed by Canada Mortgage and Housing (CMHC) here in Canada, have been primarily oriented to existing buildings and building operation. But most systems are now just beginning to adapt their systems for single-family housing and for older buildings. LEED-EB for existing buildings was launched in 2004 after a 2 year pilot phase, with about 70 buildings representing a wide variety of building types. LEED-Homes is a residential programme also in development. Working with existing buildings presents different kinds of challenges, since they cannot benefit from the kind of integrated design that save money from the outset—for example by using the building structure or envelope as part of the building’s heating or cooling system.

Two final considerations must be raised. First is the possibility of expanding building assessment systems to include social criteria of sustainability. Because commercial development is dominated by the corporate sector, such criteria have been slow to intrude into the predominantly technical mindset of building assessment. But there have been pressures to expand the realm of values to larger contextual and ethical issues (J. A. Todd et al., 2001; Wooley, 2000; Wooley & Fox, 2000). These include questions of ownership vs. stewardship; of bioregional economics vs. globalization; of economic growth vs. sufficiency; of banning whole classes of toxic materials like PVC; and the role of buildings in shaping public space.

A somewhat related consideration is the sufficiency of the “market transformation” approach that has predominated in Britain and North America. BREEAM and LEED are essentially voluntary systems that presume existing markets can be “transformed” (Cole, 1999), or perhaps more accurately, don’t need to be transformed too much in order for information to have a substantial environmental effect. The next few years should give some indication as to whether and to what degree this is true. My personal view is that, while the existing systems leave much to be desired, there will soon likely be pressure from corporate circles to “level the playing field” for their newly-acquired expertise in green building. Regulatory action can affect markets, but market transformation can also create regulatory pressure.

Eco-Labelling

Another expression of alternative value is eco-labelling. Its purpose is to provide the consumer with clear simple compact evidence of a product’s environmental quality.

The number of building materials covered in the national systems is not great, primarily because building materials are the subject of other evaluation processes that serve essentially the same purpose. But the numbers are growing, as many of these systems interpenetrate. The two categories of building materials that are most prominent in eco-labelling systems are paints and varnishes, and wood products. Wood certification is particularly important area, and I will devote special attention to it in the next section. There are three kinds of eco-labelling, set out by the International Standards Organization (ISO) in its document ISO 14020 Environmental Labels and Declarations – General Principles. Type 1 is the most well-known, "stamp of approval" labels that include the major national systems, like Environmental Choice (the "Ecologo" system) in Canada) (Figure 10), Green Seal in the US (Figure 11), the Flower of European Union (Figure 4), and Nordic countries' Swan. These systems are given for a product meeting a set of criteria determined by a third party evaluating group. Most often these groups employ process life-cycle analysis (LCA) as the means of evaluation.

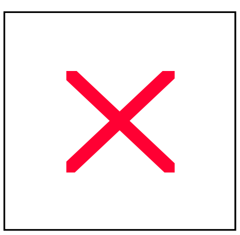
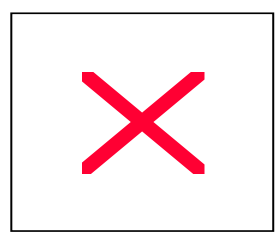


Figure 10. Canada's Eco-logo

Figure 11. U.S. Green Seal Eco-logo



Type 2 eco-labels are self-declaration labels, most commonly stating a percentage of recycled or recyclable material. The ISO provides guidelines for testing and verification methodologies for an organization making such a declaration. There is however a fair amount of abuse within this category by unwarranted claims or rhetorical adjectives, like "earth friendly", "hypoallergenic", "natural", "ozone friendly".

Type 3 labels are known as "report card" or "score card" labels. They are voluntary reports of quantified data that have been verified by a third-party evaluating organization.

Eco-labels have developed in a fairly short span of time in response to growing public interest in both health and environmental concerns. First appearing in 1977, by 1989, there were 17; by 1997, there were 49 (Hes, 2000). In 1994, the Global Eco-labelling Network (GEN) was formed—a non-profit association of third-party, environmental performance labelling organizations. By 2001, it included twenty-six national and multinational member organizations, some public, some private. GEN's purpose includes fostering co-operation, information exchange and harmonization among its members, promoting eco-labelling internationally, and encouraging both the demand for and supply of more environmentally responsible goods and services (Global Eco-labelling Network, 2005).

Public debate about eco-labelling has focused on two areas: first, the credibility and meaningfulness of the label; and secondly, the relationship between eco-labelling and international trade.

The very nature of eco-labelling—an attempt to influence the market through a simple and compact categorization—has built-in endemic problems. While increasing numbers of labelling programmes have tried to base their certification on rigorous LCA, the simplification intrinsic to a label always carries the risk of over-simplifying, and also presents opportunities for outright abuse. It is tempting for corporations to employ meaningless labels purely as a means of public relations and marketing. “Greenwashing” has become a major phenomenon of contemporary corporate marketing, one that has considerably eroded public confidence in many forms of labelling. Regulatory standards can help, but ultimately an informed public is the ultimate solution. To this end, the Consumer’s Union, publisher of Consumer Reports, initiated, April 2001, the eco-labels.org website to act as a watchdog for the North American market. The CU has developed a set of criteria to measure the credibility of labels, and fairly comprehensive information on most labels seen in North America (Consumers Union, 2002). It emphasizes five criteria that make a good label. The label should be:

- Meaningful and verifiable, with standards verifiable by an independent organization.
- Consistent and clear, with an eco-label used on one product having the same meaning if used on other products.
- Transparent, with the organization behind the label making information about organizational structure, funding, board of directors, and certification standards available to the public.
- Independent and free from conflict of interest, with those establishing standards having no funding from product sales.
- Provide opportunities for public comment, with certification standards developed with input from multiple stakeholders including consumers, industry, environmentalists and social representatives in a way that doesn't compromise the independence of the certifier.

The second major area of controversy surrounding eco-labelling is its impact on international trade. It seems to me there are two dimensions to the trade issue. The first is a phoney but understandable "problem" arising from the fact that forms of qualitative value like eco-labelling inevitably put restrictions on capitalist trade that seeks only profit, regardless of the social or environmental cost. These trade conflicts will naturally be sharper on the international level where corporations have more freedom from regulation. It is on the level of global markets that a general assault on national economic regulation is based. Many have argued that eco-labelling may already be in violation of the WTO's Agreement on Technical Barriers to Trade, and a number of significant international trade disputes have centered on eco-labelling—most notably with Canada and the US arguing that the EU's restrictions on genetically-modified foods are an unfair restraint on international trade. Norway and the EU, among others, are requesting that eco-labelling be put specifically on the agenda of the Millennium Round of the WTO negotiations, to make sure that eco-labelling is recognized as appropriate and desirable (Reynolds, 1999).

There is a second—to my mind, more legitimate—concern about eco-labelling and trade that corresponds to the corporate abuse of labelling, and also to the need for better international coordination in the development of labelling standards. This coordination must take into account power differences in the global economy and make sure that poor countries, especially those forced into dependence on global markets, are not unduly penalized by the use of environmental standards.

Although a 1998 OECD study did not find any actual use of eco-labelling as a means of unfair trade practice by national governments, it admitted that the potential for abuse existed, and should be avoided by greater international cooperation. This potential is greatest in the cases where the label standards included criteria related to the production phase of products, like water and air pollution. Most eco-labelling systems have focused on characteristics like recycled content and disposal-phase concerns (Organisation for Economic Co-Operation and Development (OECD), 1998). Because so much production today is international in character, expanding the scope of environmental assessment to the full life-cycle of materials inevitably creates international economic challenges. And concerns with production will certainly increase as LCA increasingly becomes the basis for product evaluation.

There are surprisingly few studies to date to demonstrate the positive effect of eco-labelling to reduce environmental damage (Hes, 2000), and other studies suggest only a “moderate” effect of labelling so far in changing consumer behaviour. Nevertheless it seems clear that eco-labelling has great potential as environmental consciousness grows. It has been shown that such labels do increase product sales, and increasing numbers of companies feel it worth the trouble and expense of certification. Furthermore there are indications that government approval for, and encouragement of, eco-labelling has had a noticeable effect on market behaviour. This impact is more than noticeable when government is also actively involved in “green procurement”—that is, buying green products for its own use. Governments are large enough to constitute substantial markets in themselves. The problem is that, outside Europe and the Nordic countries, pro-active government support and procurement has been very limited.

Later in this thesis I will look more closely at the role of both the state and forms of community consumption that can realize the potential of eco-labelling in market transformation.

Wood Certification

In building, the most significant form of labelling to date involves wood products. Of the forests which once covered three-quarters of the Earth's surface only one-fifth of that forest cover remains healthy and intact (Bryant, Nielsen, & Tangley, 1997). While traditional forms of forest protection have had some success in protecting specific forests, they have had little effect on the overall rate of deforestation. Building construction accounts for almost half of wood consumption in North America (Edminster, 1997), and changes in the quantity and quality of wood used in construction can have a major impact on global ecosystem regeneration.

Wood certification emerged from activism of the rainforest preservation groups that in the early eighties organized widespread consumer boycotts of "bad wood" from tropical rainforests. In the UK, Friends of the Earth (FoE) developed a "good wood scheme" and in 1989 proposed that the ITTO study the possibility of a certification and labelling plan. That effort—along with early 90s efforts in the European Union to establish performance certification—met stiff and successful resistance from the forest industry.

In the North America, the Rainforest Alliance spawned the nonprofit SmartWood Program, the world's first certifying organization, in 1989. Shortly after, the for-profit certifying enterprise Scientific Certification Systems (SCS), expanded into forest certification.

After the 1992 Rio Earth Summit failed to agree on a proposed Global Forest Convention, non-governmental initiatives for wood certification culminated in the founding of an international organization, the Forest Stewardship Council (FSC), in Toronto in 1993. The FSC included diverse interests from 25 countries, including environmental organizations like WWF and FoE, foresters, timber retailers, indigenous people's organizations, etc. Its mandate was to combine environmental, social and economically appropriate forestry through a voluntary accreditation programme for certifiers of forest products (von Mirbach, 1997). Its founding also coincided with a broadening of global forestry concerns from a narrow focus on tropical rainforests to a general concern with temperate and boreal forests as well (Kiekens, 1999).

The FSC has a tripartite structure, with voting supposedly balanced between environmental, social and economic "chambers". At the international level, some effort was also made to make sure each chamber achieved a balance between northern and southern interests.

The FSC's "Principles and Criteria" (P&C) is the central document defining its understanding of good forestry to be certified. These principles express not just environmental values, but also concerns with land tenure, indigenous people's rights, community relations and worker's rights. The P&C are the basis upon which the FSC accredits "third party" certifying organizations. In 1995, the FSC became a legal entity, accrediting four main certifying bodies—SmartWood and SCS (mentioned above) and in

Europe SGS-Forestry and the Soil Association. They were subsequently joined by SKAL (from the Netherlands) and the "Institut für Marktökologie" (from Switzerland).

The kind of certification promoted by the FSC is called product or performance certification. It involves careful tracking of logs and wood products over a “chain of custody” through its entire processing. It is far more complex than, say, certification of organic foods, because of the number of suppliers, contractors, processors, assemblers and retailers involved. Sustainably harvested wood products require either separate product streams in mills that are audited as part of the third-party certification process, or special tagging of certified material as it moves through the mill alongside uncertified stock (Wilson & Malin, 1997b).

Another form of wood certification, however, has come on the scene. This kind is process-oriented, a certification of the management *system* rather than specific products. The Canadian Standards Association (CSA) has been a pioneer in this approach, initiated in 1996, which takes its cue from the ISO 14000 series of environmental management standards. The emphasis is on whether the certification candidate has an adequate forest management planning process in place, and on “continual improvement” rather than on actual eco-forestry performance.

While the CSA system does have formal requirements for public participation, it has been roundly criticized by environmentalists and public interest advocates. Critics say forest managers are not required to act on the public input it receives, and in practice the CSA has certified clear-cutting in high conservation value forests and logging on indigenous peoples’ lands without their consent (Ozinga, 2001).

The substance of such certification is also a concern. Without any chain-of-custody tracking, there is no clear link between the products a company sells and its forest management system. Products themselves are not certified, and consumers can have no assurance that their purchases support sustainable forestry. The emphasis on "continual improvement" risks being interpreted far too nominally. And critics have also argued that, because of the administrative bureaucracy required for compliance, the CSA system favours large companies over smaller operators (von Mirbach, 1997).

An even more flawed "certification" system is the Sustainable Forestry Initiative (SFI) of the American Forest and Paper Association (AF&PA). It was started in 1995 by the timber association whose members control 56 million acres in the US, which is 90 ercent of industrial timberland, 84 percent of paper production and 50 percent of solid wood production in the USA (Heaton, 2001). For many observers, the SFI's certification amounts to nothing more than "greenwashing" (or environmental PR) since its standards are so weak that it had (by 2001) "certified" over 50 million acres in the US—nearly all of the American industry's timber base—along with millions of acres in Canada (NRDC, 2002). Others feel that the programme is a step by mainstream industry to gradually improving forest practices (Kiekens, 1999), and perhaps a step to more demanding standards.

Most critics are not so sanguine, however. Various comparative studies have been funded by the Natural Resources Defence Council, American Lands, National Wildlife Federation, Maine Audubon, the Pinchot Institute, and FERN in Europe, all found the SFI deficient (Natural Resources Defence Council (NRDC), 2002). According to the NRDC, "the SFI fails to:

- prevent the clearing and conversion of diverse natural forests to ecologically barren plantation monocultures—a process that has destroyed much forest habitat in the Pacific Northwestern United States and is now destroying forests and forested wetlands across the Southeast at an alarming rate;
- protect intact old growth forests in the US and high conservation value forests globally;
- protect sensitive, rare, and state-listed threatened and endangered species;
- adequately control clearcutting and specify retention of tree cover in clearings to help maintain ecosystem function. (SFI's average allowable clearcut size is 116 football fields!)"

An even more recent study (Tan, 2003, p.1) of the British Columbia forest industry released by ForestEthics, Greenpeace Canada, and the BC Chapter of the Sierra Club of Canada strongly criticized both the SFI and CSA certification programmes. The report found that CSA and SFI standards "allow a proliferation of large clear-cuts; continued logging in forests inhabited by endangered species; damages to drinking water, fisheries and streamside forests; ongoing use of chemical herbicides; accelerating losses of natural forests; and expanding tree farms."

The above report, like many originating from environmental sources, argues that the certification of the Forest Stewardship Council (FSC) is the only reliable and legitimate international system. But even the FSC has not been immune to criticism, some of it quite serious. The problem is less the validity of the system, or its Principles and Criteria, than its consistency and enforcement—problems which some have linked to the growing power of large forestry interests within the FSC.

In November 2002, the UK-based Rainforest Foundation (RF) released a report that claimed that the forest companies producing FSC-certified wood “have been implicated in gross abuses of human rights, including the torturing and shooting of local people; are logging in pristine tropical rainforest containing some of the world’s most endangered wildlife species, such as the Sumatran tiger; and have falsely claimed to comply with the FSC’s audit requirements, such as by allowing ‘uncertified’ wood to be labelled with the FSC ‘seal of approval’.” (Counsell & Loraas, 2002, p.1)

The RF report is intriguing not only because of its criticisms, but because it links them to FSC certification’s trajectory of development—evolving from a mechanism of support for discriminatory grass-roots boycott campaigns to become a major international ‘forest policy tool’ of global decision-makers. The RF sees in this “a subtle shift from the use of the FSC principally as a tool for improved forest management to one of improved marketing of forest products.”

One central focus of the RF criticism of the FSC revolves around the behaviour of the most powerful environmental member of the FSC—the WWF (known as the World Wildlife Fund in North America, and the Worldwide Fund for Nature elsewhere). The WWF has been instrumental in achieving increasing forest industry involvement in wood certification, primarily through its “Trade Networks” which now exist in 15 countries and include over 600 corporate members. A growing number of environmental and indigenous groups, however, feel that the WWF’s ambitious agenda for spreading FSC certification has considerably diluted quality control and the rigourous application of the FSC's "Principles and Criteria".

A particular concern is a partnership formed by the WWF with the World Bank in 1998. Under their agreement, they are committed to bring "200 million hectares of the world's production forests under independently certified sustainable management, by the year 2005" (WWF, 2001). This means an expansion in the area certified by the FSC by 700 % in the time period from fall, 2002 to 2005—which various groups have argued is arbitrary and unattainable. The Rainforest Foundation estimates that around 18 million dollars flowed through the WWF between 1999 and 2001 alone, and that the dollars involved in the WWF "fast growth" strategy are seriously compromising certification standards. In addition, some observers are pointing out that the "fast growth" strategy is systemically biased against community-based forestry, which historically has been nurtured some of the most ecological forms of forestry. Ironically, according to the RF analysis of the new forest policy adopted by the World Bank in October 2002, the FSC does not fully measure up to the Bank's "principles for a credible certification system"—especially that of being free from vested conflicts of interests (Rainforest Foundation, 2002).

Coincident with inadequate monitoring of the FSC's third-party assessment is growing tension within the FSC between stakeholders due to the growing power of the corporate segment. The three chambers of FSC organization are no longer equal in numbers or power, with community and indigenous representation. According to Counsell and Loraas (2002), "The economic chamber has grown fast over the last few years and now comprise about 46% of the FSC's total membership, whilst the environment chamber comprises about 36 percent and the social chamber only 18 percent. ‘Southern’ members of all FSC chambers still account for less than 30 percent of total members.” While some national FSC structures—including Canada—have done a good job in maintaining democratic balance, this is not true of many other countries like Ireland and Malaysia.

The Rainforest Foundation and other critics of the FSC are careful to emphasize that they still feel that FSC certification, properly organized and monitored, represent one of the best tools to create sustainable forestry. But their criticisms indicate dilemmas for wood certification that parallel those in other areas of alternative valuation like green building assessment. The success and growth of these systems present new problems of cooptation and corporate interest, as well as logistical problems of monitoring and management. These problems are aggravated by the growth of powerful environmental NGOs like the WWF—which has, it should be pointed out, been criticized for its activities in other realms (Isla, 2000) that risk becoming agents of a new “enclosure of the global commons” by corporate organizations.

Maintaining and extending accountability, democracy and a vision of truly ecological production is a tremendous challenge in this era of corporate globalization. But if this can be done, the possibilities are great. According to WWF studies, even at current consumption of wood, sustainably-managed forestry operations could realistically supply all of industry’s needs from one-fifth of world’s forests. In addition, the concentration of the forest industry presents certain opportunities. 90 percent of production comes from 600 million hectares in just 25 countries, and while almost half the annual wood harvest is processed by the top 50 forest products companies, the top 50 users of this wood consume 10 percent of the total. According to the WWF, "this level of concentration means that a small number of leading companies are in a position to create the critical mass required for certification to take off." (WWF, 2001, p.1).

Besides the rapid growth of forest certification in the last few years—which now amounts to 2 to 3 percent of world forest output—there are other indications that wood certification is near a mass take-off phase. A recent study of customers of BC forest products (IBM Business Consulting Services, 2003), for example, concluded that a "greenward shift" in wood product procurement was taking place and that major adjustments were taking place that would make wood certification a major part of markets in the near future.

Perhaps the most obvious testament to this shift is the 1999 decision of Home Depot—in response to persistent protests—to phase out non-certified wood in all its stores by the end of 2002. Despite some bottlenecks in certified wood supply, other retailers are being forced by public and ENGO pressure—and the Home Depot decision—to consider stocking certified wood (Krill, 2001).

Product Guides and Directories

Some of the most important people in the movement for green building are those who are compiling directories and databases of green building materials for use by builders and designers. They are at the nexus of theory and practice in green building as pertains to materials. Not only are they at the cutting-edge of green building education—shaping the values of eco-building—but they are also instrumental in creating new green markets. Examples include the online *Environmental Building Sourcebook* of Austin

Texas's Green Builder initiative; OIKOS, another online directory based in Portland Oregon; the *Guide to Resource-Efficient Building Elements* of Montana's Center for Resourceful Building Technology; the *Environmental Resource Guide*, a hard copy and CD-ROM directory, published between 1992 and 1999 by the American Institute of Architects (AIA); and the *Green Spec* database, in hardcopy and online, organized by the publishers of the Environmental Building News. There are also a growing number of regional directories because "what is green" depends so much on local conditions and resources.

While these groups have worked hard to support and encourage more technical research and evaluation, their focus has had to be eminently practical since their clientele is the architects, engineers, builders, retailers and renovators engaged in everyday acts of building. In the absence or scarcity of complete information, they have had to be somewhat eclectic in their assessment of what products to recommend and promote. Rarely are the publishers of these directories engaged in basic LCA themselves, but they try to synthesize available information, drawing on both available hard LCA data, and more qualitative analysis. They have often had to compare apples and oranges within the same category—for example, comparing the energy-intensity of one product with the toxicity of another (Wilson, 2000). Some products in a certain category might be the greenest simply because the available alternatives are so destructive (for example, CCA-treated wood or PVC plastic). Many products are the "lesser evil" and, with almost all products less than perfect from an environmental perspective, most choices are a compromise between environmental quality and reality.

In any case, there is no single ideal roofing or flooring or insulation because every context is different. The directories mentioned above, as well as other materials databases, usually try to provide guidelines for selection, based on the design goals of the construction project. For some projects, price may not be a major concern, making environmental quality a top priority; other projects may have to be done as environmentally as possible under tight budgetary constraints. Product information is no less important to each case.

Although some of the environmental product directory projects have attempted to provide overall environmental guidelines for product selection, most have focused on best case choices. That is, the directories are not concerned primarily with evaluating all building materials, but mainly listing those that can be considered the greenest. To be listed, therefore, is something of an endorsement.

Because new products and are emerging all the time, new materials knowledge continues to evolve, the tendency is for the directories to raise the bar, and increase their criteria of what is green. Authors of the Green Spec directory, for example, have given notice that the next edition of the directory will purge a number of current product listings—simply because products of higher environmental quality are becoming commercially available.

Here are some examples of positive criteria employed by the green products directories to select their products:

- ♦ products with low embodied energy and that are produced with fewer resources (e.g. recycled flyash concrete).

- products produced with renewable energy, and/or made with recycled, reclaimed or salvaged materials.
- products made with organically-grown natural materials or agricultural waste (e.g strawbale walls)
- products with great durability
- products that can be easily recycled or reused at the end of their product life.
- products that avoid toxic emissions and contribute to better indoor or outdoor air quality (e.g. low-v.o.c. paints)
- products that constitute alternatives to especially commonplace and destructive materials like CCA-treated wood and polyvinyl chloride (e.g. ACQ-treated wood, bio-plastics and natural linoleum).
- products that reduce building energy or water use (e.g. super-windows)

A checklist compiled by the Environmental Building News' in developing its Green Spec directory is found in Table 2.

A product might qualify for recommendation as "green" not necessarily because of how it rates in one of these criteria but because it ranks reasonably well in more than one category.

Depending on the clientele of the directory, many other more specific criteria can be added—which might be social and economic as well as environmental. For example, a regional directory might place greater emphasis on products that make good use of a local resource, or that create local jobs throughout its product life. For some, the quality of the jobs might be especially important. The Sustainable Materials Database, for example, a project of the Center for Sustainable Buildings Research at University of

Minnesota, is designed to fit seamlessly with use of its Sustainable Design Guide and the LEED building rating system of the US Green Building Council. One of its criteria is local manufacture (Foss, 2002). Other directories prioritize local jobs, good working conditions, supportive of aboriginal land claims, etc.

Summary of Product Standards for GreenSpec

1. **Products Made With Salvaged, Recycled, or Agricultural Waste Content**
   - 1a. Salvaged products
   - 1b. Products with post-consumer recycled content
   - 1c. Products with post-industrial recycled content
   - 1e. Products made from agricultural waste material
2. **Products That Conserve Natural Resources**
   - 2a. Products that reduce material use
   - 2b. Products with exceptional durability or low maintenance requirements
   - 2c. Certified wood products
   - 2d. Rapidly renewable products
3. **Products That Avoid Toxic or Other Emissions**
   - 3a. Natural or minimally processed products
   - 3b. Alternatives to conventional preservative-treated wood
   - 3c. Alternatives to ozone-depleting substances
   - 3d. Alternatives to products made from PVC
   - 3e. Alternatives to other components considered hazardous
   - 3f. Products that reduce or eliminate pesticide treatments
   - 3g. Products that reduce pollution or waste from operations
4. **Products That Reduce Environmental Impacts During Construction, Demolition, or Renovation**
   - 4a. Products that reduce the impacts of new construction
   - 4b. Products that reduce the impacts of demolition
   - 4c. Products that reduce the impacts of renovation
5. **Products That Save Energy or Water**
   - 5a. Building components that reduce heating and cooling loads
   - 5b. Equipment that conserves energy
   - 5c. Renewable energy and fuel cell equipment
   - 5d. Fixtures and equipment that conserve water
6. **Products That Contribute to a Safe, Healthy Indoor Environment**
   - 6a. Products that don't release significant pollutants into the building
   - 6b. Products that block the introduction, development, or spread of indoor contaminants
   - 6c. Products that remove indoor pollutants
   - 6d. Products that warn occupants of health hazards in the building
   - 6e. Products that improve light quality

Table 2. Typical Green Product Criteria
Source: Wilson, 2000

The guide or directory projects are perhaps the most interesting initiatives in appreciating the subtleties of the both the creation and the expression of alternative value in the building industry. It is a dialectic of the ideal and the actual. The guide publishers must often make very subjective value judgements about what is the best strategy to advance green building practice. For example, regional directories (like the one the author was involved with in 1994-96) must make decisions as to whether listing a "green" product made far away, but not produced locally, encourages or discourages the eventual local production of the product; or whether the endorsement of a less green local product is better than support for a more ecological product made elsewhere.

The directory projects are also faced with very practical concerns about liability and financing. Liability concerns are particularly great for guides that give products a specific rating. Large corporations with substantial legal resources will not hesitate to sue for libel or misrepresentation of their products. Even more common "best case" directories that only list products have been subject to intimidation by corporations that see the exclusion of their products as misrepresentation or unfair trade practice.

Even governments are subject to corporate intimidation. In New York state, for example, the Resilient Flooring Association, a front for the vinyl industry, attempted to challenge the state's progressive new green building standards, which do not include polyvinyl chloride (PVC) as a recommended "green material". The Association's suit was withdrawn before a state court was likely to rule against it (Greenbiz.com, 2003), but served notice that any possible transition away from PVC would be made as costly as possible by vinyl industry resistance. (This will be discussed further in the next chapter).

Financing is another practical difficulty for the directory projects. As with many important green economic areas (e.g. energy conservation), there is (as yet) no powerful financial interest group to support eco-materials development and education. These initiatives usually employ a mix of government grants, membership customer subscriptions, and corporate sponsorship. The Environmental Building News's Green Spec guide (accessible at http://www.buildinggreen.com/) makes no money from industry sources since it wants its guide to have complete credibility as a source of ecological information. As of February 2005, it was charging US$12.95 for one-week on-line access to the directory; US$199 for one-year electronic access (including a subscription to the Environmental Building News monthly newsletter); and was selling a hard-cover version for US$89. Green Spec has detailed listings for more than 1,850 green building products with environmental data, manufacturer information, and links to additional resources.

The Austin Green Builder Sourcebook (accessible at http://www.greenbuilder.com/sourcebook/) does accept corporate sponsorship for chapters of its guide. It tastefully lists the sponsors on its website directory, but does not have ads. The Sourcebook is a well-respected information source in the green building community throughout the US, and the acceptance of corporate sponsorship does not seem to have affected its critical standpoint. The Montana-based CRBT's guide (accessible at http://www.crbt.org/) is funded by the US Brown Foundation. Its foundation funding is quite typical of the way many of the free online directories are funded. Other projects combine corporate contributions, government and foundation funding, and customer fees.

Steve Loken (Loken, 2002b), the founder of the CRBT, articulates one of the practical dilemmas of the directory projects in his introduction to the CRBT guidebook:

> The Guide cannot be all things to all people. The mainstream building industry sometimes criticizes it for being too radical. Meanwhile some environmental groups lambaste it for including specific resource efficient products made by companies with general reputations for environmental degradation.

The decisions made by Loken and his colleagues depended very much on their subjective judgement about what would be in the best long-term interests of green building. Promoting innovative products made by otherwise not-so-green companies might either be a means of encouraging incremental transformation of corporate production or simply reinforcing a small niche market that the corporation might use to greenwash its public image. Even the most radical green initiatives must make judgment calls that guarantee no certain outcome. And this will be increasingly the case as the green building movement grows and incorporates the involvement of mainstream producers and professionals.

CHAPTER III: PRODUCTION
MATERIALS IN GREEN INDUSTRIAL STRATEGY

The preceding discussion of value presumes that there are alternatives to mainstream forms of resource-intensive and toxic production. A crucial purpose of materials evaluation and certification is to encourage more ecological design and production of materials. For this reason, it is important that we look specifically at the production of building materials to understand how postindustrial green manufacturing would differ from industrial production. This chapter will build on Chapter I of this dissertation, and on Chapter 9 of *Designing the Green Economy* (Milani, 2000)—on possibilities for manufacturing and resource use in a green economy—surveying concisely the general character of green production potentials. Appreciating this character has great implications for both building materials and community economic development strategies.

In the first two chapters, I introduced three principal tendencies of postindustrial economic development: *decentralization, dematerialization* and *detoxification*. They are potentials that should emerge spontaneously from economic development, but have been suppressed or distorted by the social power relationships behind the economy's rules and driving forces. While nevertheless still visible in partial forms in industrial capitalism, the "3D's" are the essence of authentic green economic development, and they are what makes the green economy "postindustrial".

In this chapter, I will illustrate how these tendencies can be, or are being, expressed by looking at the potential *form* and *content* of green production. While this distinction between form and content can be useful, one of the main lessons to be learned is that the form and content of postindustrial development cannot be separated—in the same way that decentralization, dematerialization and detoxification *require each other* to be fully implemented. Minimizing resource use, for example, requires a circular looped economy, well-adapted to local conditions, that circulates materials benign enough to be safely used for multiple purposes and eventually returned to nature as compost. The task of minimizing the use and dangers of toxic materials is, conversely, greatly aided by reducing the overall volume of materials flow in the economy. And all three processes—along with the form and content of the economy—are all accelerated by the value revolution that puts *services* (to meet human and environmental need) rather than goods at the centre of economic development.

The following sections will attempt to survey the basic principles of green production, as well as some special issues of green production with particular relevance for building materials today: e.g. indoor air quality in buildings, the role of plastics, of concrete and of engineered materials. Many important issues relating to service-production and extended producer responsibility (EPR) will have to be left to Chapter VI on regulation. Some increasingly important forms of green production—that of natural materials like strawbale and rammed earth—deserve special treatment in a chapter of their own (V). By the same token, many of the specific expressions of "production in loops" will be discussed more concretely in the next chapter (IV) on recycling, reuse and deconstruction.

The Form of Service

Green manufacturing produces material things, but it does so primarily as a *means to provide services* to meet human and environmental need. It tries to directly target end-use and service needs—such as nutrition, access, entertainment—and works backwards to find the most elegant and efficient ways of meeting these needs. This end-use approach allows major savings in materials and energy. Such resource-efficiency is cultivated even further by the green economy's cyclical form, mimicking the closed-loop organization of nature—where every output is also a useful input and there is no waste.

In most of the popular literature about green economics, there is more awareness of the need for recycling than for service-oriented production. But the two dimensions go hand-in-hand in the eyes of industrial ecologists. The very logic of conservation in fact leads to service production.

Figure 12 (next page) is a representation of various strategies for cycling materials and for what is called product life extension. It shows the course of a life cycle that can get the most out of our use of materials. But it also shows that that all "loops" are not the same, and that various social and economic benefits accrue from focusing a product's life on the tightest loop of production-consumption—reuse.

What the popular mind commonly calls "recycling" is actually a continuum of activities, ranging from recycling on one side (the largest loops), to technological upgrading, to reconditioning and remanufacturing, to repair and finally to pure reuse (the tightest loop) on the other side. The smaller the loop, the less is energy is required; the more skilled and service-like the work tends to be; and the more local-regional the process is. Proximity is highly desirable for systems based in reuse, while conventional recycling is more consistent with globalization's giant loops of production and consumption. Reutilization activities also reduce the *speed of flow* of materials through the economy, something which recycling does not do (Stahel, 1994). Keeping as much as possible of the economy's materials circulating in the #1 loop is basically a design question, involving both the design of products (e.g. design for disassembly) and the design of economic relationships and infrastructure.

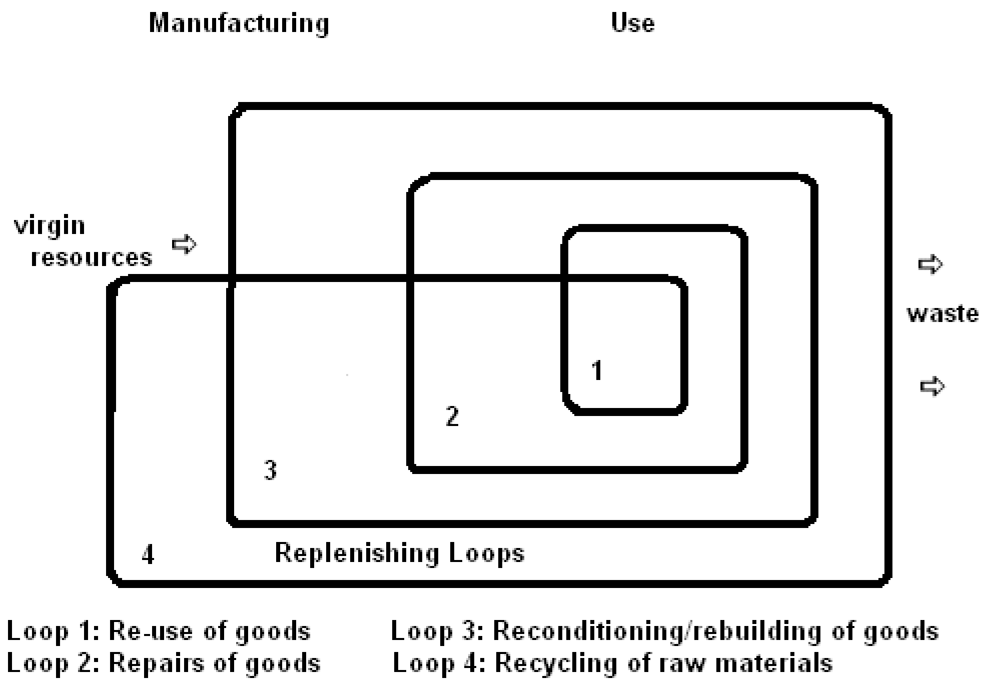


Figure 12. Product Life Extension Strategies
Source: Jackson, 1996

A focus on various forms of recycling and reuse radically changes the relationship between what is normally called primary and secondary manufacturing industry, and this in itself has great implications for both pollution and the nature of work. Primary industry is the processing that immediately follows the extraction of raw materials. It involves separating pure materials from the mixed extracted form using physical, chemical and thermal processes. The materials are converted into finished materials like fuels, refined metals and alloys, and industrial chemicals which will in turn be used by secondary manufacturing industries like textiles, auto manufacturing, etc. Primary processing includes smelting of ores, cracking petroleum and cement production. By and large, it is very dirty and energy-intensive work, generating massive amounts of waste by-products. Four primary materials processing industries—metals, chemicals, paper and plastics—generate 71 percent of the US's toxic air releases (Geiser, 2001, p. 6). And the energy used by the paper, steel, aluminium, plastics, and container glass industries account for fully 31 percent of US total in manufacturing (Young, 2000; Young & Sachs, 1994). Mining and smelting take an estimated 5 to 10 percent of world energy use each year (Durning, 1992). According to Stahel (1981), about three-quarters of all industrial energy consumption is associated with the extraction or processing of basic materials like steel and cement, while only about one quarter is used in the transformation of materials into finished goods such as machines or buildings.

The converse is true of labour, with about three times as much work being employed in the conversion of materials to finished products as is required in the production of materials. Thus simply altering the balance between primary (and extractive) industry and secondary manufacturing has tremendous implications for job creation. Going a step beyond that—towards an increase in ecological transformation-type industries such as reconditioning—corresponds to a massive substitution of creative work for energy and materials. The work done by skilled craftsmen in repair and reutilization industry, it should be noted, is typically done in smaller workshops dispersed through local economies. This has major implications for community economic development and the quality of work life.

Green economies would shift extraction industry to the cities, as “wastes” became “resources”. Real efficiency in a postindustrial world means using knowledge to make the most of available resources. Cities are a tremendous source of fertilizer and materials, and yet current practices make them problems of organic and solid waste. Cities’ abundant organic matter should be a fertile source of vegetation for food, water and air purification, energy, climate control and even industrial feedstocks. Solid “wastes” should make cities the mines and factories of postindustrial production based in recycling and reuse.

It is important to recognize that economic organization based on reuse and service represents a challenge to capitalist values of accumulation. This is not because there is no profit in service/reuse-based production; quite the contrary. But it is because closed-loop economies require new forms of liability—extended producer responsibility (EPR)—that ensure that companies take responsibility for the materials they produce throughout their entire life cycle (Stahel, 1994). There are great opportunities for profit here, as evidenced by Xerox selling document services rather than equipment (which it maintains ownership of, and which it now designs for disassembly); Interface flooring that sells carpeting services rather than carpeting; and various chemical companies that are now selling Integrated Pest Management services, rather than insecticides. Most corporations, however, feel very uneasy with the extended forms of liability, which demand new forms of management and often discourage the large loops of production and consumption intrinsic to globalization. They feel much more comfortable with conventional recycling, high-tech incineration and "end of pipe" pollution control measures that are, despite the expense and energy-intensity of these measures, still consistent with old forms of capitalist ownership, property and liability. In the old system, producing and selling lots of stuff is the main concern, and once a product is sold, it is someone else's problem. If the responsibility for materials is placed at the feet of producers through EPR legislation, they are forced to get quite creative on the level of product design, finding innovative ways to conserve materials and make products out of benign substances. In Chapter VI, I will return to the relationship of this kind of regulation and green development.

Eco-Industrial Development

Perhaps the most obvious attribute of authentic postindustrial production is its decentralization—especially its character of being "distributed" over the landscape and community (Lyle, 1994). Thus far, this trend is more visible in the evolution of energy systems, where massive power plant production is giving way to fuel cells, photovoltaic roof shingles and other technologies that are beginning to turn ordinary buildings from being passive consumers of energy into decentralized producers.

The typical individual building will likely not become a source of its own materials in the future, but we will nevertheless see massive recycling of existing building materials and assemblies, along with materials production that is much more locally- or regionally-based. And, as I will illustrate in the chapters on deconstruction and "natural building", increasing portions of our building materials stock will come from our immediate environments. As noted above in the previous section, reuse-based production and secondary materials industry is much efficient when local and regional.

Closed-loop production is not just more local than conventional industrial mass production, it is also more diverse and less monocultural. If all by-products of manufacturing are to be used creatively and benignly, this requires that a variety of firms and processes be grouped together that can complement each other. As in nature, this works best with intentionally multi-functional design where any process always has multiple and overlapping effects. So while it is true that green manufacturing tends to be more decentralized than conventional brown industry, this is not an arbitrary and chaotic dispersal of production units. The importance of symbiotic and complementary relationships demands new levels of cooperation and the intelligent clustering of firms.

Over the last ten years the parallels between nature and sustainable production systems have been explored most deeply by the emerging discipline of industrial ecology. One of its pioneers, Robert A. Frosch (1992, p. 800), describes these connections:

> The idea of an industrial ecology is based upon a straightforward analogy with natural ecological systems. In nature an ecological system operates through a web of connections in which organisms live and consume each other and each other's waste. The system has evolved so that the characteristic of communities of living organisms seems to be that nothing that contains available energy or useful material will be lost. There will evolve some organism that will manage to make its living by dealing with any waste product that provides available energy or usable material. Ecologists talk of a food web: an interconnection of uses of both organisms and their wastes. In the industrial context we may think of this as being use of products and waste products. The system structure of a natural ecology and the structure of an industrial system, or an economic system, are extremely similar.

Industrial ecology goes at least one step beyond previous forms of thinking on "eco-efficiency" and "pollution prevention" because it has moves beyond the individual firm to look at systems. It is one of the more important expressions of the new ecological economics that sees the human economy as a subsystem of nature. It suggests that we not only need to acknowledge the limitations provided by natural systems, but also understand that our most productive strategies are usually those that imitate or mimic nature: what has been called "biomimicry". IE has by no means made concerns with firm-level eco-efficiency or pollution passé, but has enriched these activities by highlighting new possibilities for cooperation and system renewal.

Most of the practical influence of industrial ecology has been on the design of eco-industrial parks and networks. Inspired initially by the spontaneous emergence of the industrial park in Kalundborg Denmark in the late eighties (Tibbs, 1992), the discipline has helped in the more conscious creation of eco-industrial parks all over the developed world. Probably the most quoted definition of the Eco-industrial Park (EIP) comes from the (US) President's Council on Sustainable Development (1996): "An Eco-Industrial Park is a community of businesses that cooperate with each other and with the local community to efficiently share resources (information, material, water, energy, infrastructure, and natural habitat), leading to economic gains, gains in environmental quality, and equitable enhancement of human resources for businesses and local community."

Usually the EIPs are firms situated together to best use each others' waste heat and process by-products, but besides that, there is a great deal of variety in the character of different EIPs. Some, like Burnside Park in Dartmouth NS, have emerged from the effort to create useful and profitable linkages between firms in an existing industrial park. Others have been consciously designed from the outset for various purposes—social, economic or environmental. These include ecological brownfields development, with an emphasis on environmental justice and community development (Cote & Cohen-Rosenthal, 1998). Another variety is the green technology development park, where the emphasis is more on the sharing of knowledge. Another common EIP is the kind organized around materials recovery (e.g., a Resource Recovery Park) or around another "anchor" facility, like a core industry or infrastructure facility for wastewater treatment or energy production (Lowe, 1997). Some of the anchors are large industrial enterprises, while some parks are oriented much more to small and medium-sized firms. Some parks are privately owned and run, some coordinated by the state.

Eco-industrial development is still in its early stages, with many of the pioneering parks hardly representing ecological ideals. For example, the prototype Kalundborg park is anchored by a coal-fired power plant. But increasingly radical projects are emerging each year, with many combining "industrial ecosystem" organization with community development and the production of non-toxic benign materials. Here I will focus on a few of the models for eco-industrial park development that have special relevance for building materials:

- Materials Recovery Facility EIP: A Materials Recovery Facility (MRF) serves to match the wastes of a company or community with the resource needs of another. MRFs are a means of local economies beginning to "mine the waste stream" by turning waste into a resource. This kind of EIP can be focused primarily on building materials, or more generally on corporate or municipal waste. Construction and demolition (C&D) waste amounts to up to a third of municipal waste. The recycling of some forms of C&D waste can contribute to production of other kinds of products, and many kinds of non-construction waste can be directed towards the production of building materials. For example, certain kinds of recyclable plastic can be made into plastic or wood-plastic composite lumber. And glass can be used to make glass tiles. MRF-based parks can be integrated with Reused Building Materials Centres, places which short-circuit landfills altogether and avoid the mixing and separating stages.

- Green Technology EIP: Most Green Technology EIPs are not primarily oriented to materials or resource sharing; their tenants tend to be more interested in shared services, information sharing, pollution prevention and cutting-edge green technologies in any number of areas. They typically act as incubators for environmental innovation. Very often they are made up of advanced green buildings, using minimal energy, employing renewable energy sources and featuring the most ecological materials in their construction. They tend to be models of ecological building and site management. Variations on the Green Technology EIP hold great promise as showcases for green building materials, not just in their own construction, but as locations for green building materials showrooms and retailing centres. Ideally, some retailing centres would also incorporate features of MRF-EIPs because of the importance of reuse and recycling to green building material markets.
- Bio-Materials EIP: As I will discuss later in this chapter, the production of plant-based materials—and cultivation of a “Carbohydrate Economy”—is an essential means of detoxifying production and lessening the power of the petrochemical

industry. One of the most interesting developments in EIP development is the creation of parks organized around the industrial use of plant materials, usually agricultural waste products or by-products. An EIP in St. Peter Minnesota (a rural community of about 10,000 people) is transforming a 160-acre grass-strip airport runway into a high-performance industrial park focused on making the most of the agricultural resource base in the area (Osdoba, 2002). Organizers want to direct more local food production to the food needs of local people, and also to diversify into production of biodiesel fuels, biochemicals and even bioplastics. A similar and more mature EIP is the Intervale Food Centre in Burlington Vermont, which is less concerned with biochemical production than a range of other food-related forms of production, including biomass gasification, aquaculture and "living machine" waste water treatment (Bamburg, 2002). Even more ambitious EIPs geared to bio-material development, called bio-refineries, are being initiated by the Geneva-based Zero Emissions Research Institute (ZERI) which I will discuss later. Building materials are a strategic area for incremental substitution of bio-based materials for petrochemicals, and their production in EIPs would be a major contribution to green economic development.

Eco-industrial networks are the next step in building industrial ecosystem organization. These networks can range from what have been called "virtual EIPs," that involve sharing without immediate proximity, to whole regional economies. As discussed in my earlier book (Milani, 2000), industrial ecologists have put a more ecological slant on the phenomenon of "flexible manufacturing networks" (FMNs) which have been used so successfully by certain regions—like “the Third Italy”—in the Post-Fordist global economy (Sabel, 1994). FMNs are networks of small firms that, through cooperation, can take on tasks that normally could only be handled by large corporations. The creation of green economies requires the creation of green FMNs that combine cooperation with the conscious creation of bioregional economic relationships.

The combination of eco-industrial organization, the selling of services, and reuse and design-for-disassembly, and EPR does not mean the economy of the future will be completely localized, but that a very different balance between global and local would ensue. According to Walter Stahel (1998),

> A service society will not solve all problems for society, and especially not the problems inherited from the past (e.g. pollution clean-up, unemployment of over-specialized production workers). Neither will it make the manufacturing sector disappear. But it could well restructure it, into firms manufacturing high volumes of global standardized components, and regional firms specialized on assembly, disassembly and re-manufacturing of products. This is a trend that can already be observed in electronics and aviation technology.

Detoxifying Production

One of the weak areas of concern in industrial ecology to date has been detoxification. This is perhaps understandable with the roots of IE in modern business and allied academia. Questions of eco-efficiency and conservation might seem more immediately relevant to the corporate bottom line; and toxic chemicals have become almost ubiquitous in industry. Over 60,000 chemicals are now used in industrial production, with the US EPA estimating that 15,000 nonpolymeric chemicals are produced or imported into the US each year. And each year the materials industries add another 1000 chemicals to this list (Geiser, 2001, p. 5). A 1997 U.S. EPA study found that of the 3,000 chemicals imported or produced in the United States in amounts above one million pounds, 43 percent had no publicly available data on toxicity, and only 7 percent had a full set of basic data on impacts and persistence (Avril, 2003).

Some readers of this dissertation might find it counter-intuitive to suggest that detoxification is a primary tendency of postindustrial development. They might find elements of decentralization and dematerialization in the mainstream economy, but very little detoxification. Nevertheless, while the potential for detoxification does clearly run against the status quo, it is possible to see the shadow of this potential in certain key areas. The most apparent is in what energy analysts call the “decarbonisation” of energy systems. That is, over the last 150 years, economic development has gradually substituted cleaner forms of energy for dirtier ones—from charcoal to coal to oil to natural gas, and now hopefully to renewables and soft energy systems. The rise of oil and the oil-based chemical industry has introduced vast numbers of toxic chemicals into daily use, but in the last decade increasing numbers of more benign plant-based materials have become cost-competitive with petrochemical substances. They are part of a rising “Carbohydrate Economy” of bio-based materials that are far more benign than petrochemicals. It is the material expression of what we see more clearly in energy: a growing potential to shift back to renewable resources made possible by growing scientific and ecological knowledge (Morris & Ahmed, 1993). While this transition is not inevitable, neither is our survival as a species. But it is the logical thrust of technological and economic development, and absolutely necessary to establish sustainable economies.

Detoxification is an essential dimension of green production. For the "food webs" of eco-industrial organization to work properly to eliminate waste, all outputs and by-products have to be non-toxic and "nutritious" enough to be used as inputs for some other process, and eventually to be safely returned to nature (Tibbs, 1998).

The toxicity of the modern economy is essentially a symptom of design failure, or outright absence of design. Certain materials are toxic because they are intended to be—e.g. pesticides, disinfectants, etc. Other materials—catalysts, solvents, etc.—are not toxic by intent but because their functional properties or chemical structure makes them likely to be. The toxicity of other materials—like many metals like cadmium and lead—is completely unrelated to their functions—e.g. providing flexibility or corrosion-resistance or pigmentation (Geiser, 2001, p. 336). Especially in the last category, there are materials that can be substituted for the toxic ones to accomplish their purposes. Increasingly this is true of the second category. And in the first category—intentionally toxic materials—more often than not we find that poisoning is a substitute for proper design. This is particularly true in agriculture where the use of industrial chemicals not only poisons the food system, but interferes with the proper cycling of nutrients in the soil. The killing of organisms in the supposed interest of health undermines the diversity and vitality upon which real ecosystem health depends.

The starting point for detoxification begins with this examination of why materials are toxic, and then evaluating them in terms of their toxicity, persistence and bioaccumulative capacity—as discussed in Chapter I and illustrated in Figure 2.

Creating appropriate production processes also depends on understanding the kinds of materials cycles possible. In Fig. 13, the large loop represents natural cycles. Cell 2 is the human economy, which has exchanges with nature, but also material flows that are isolated from natural systems. By rights, the materials interacting with nature—what McDonough & Braungart (1998; McDonough & Braungart, 2002) call "biological nutrients"—should be almost completely benign and biodegradable, and those that flow continuously within the economy without cycling back to nature should be the most toxic. McDonough & Braungart call the latter "technical nutrients" that should be well sealed in their closed loops.

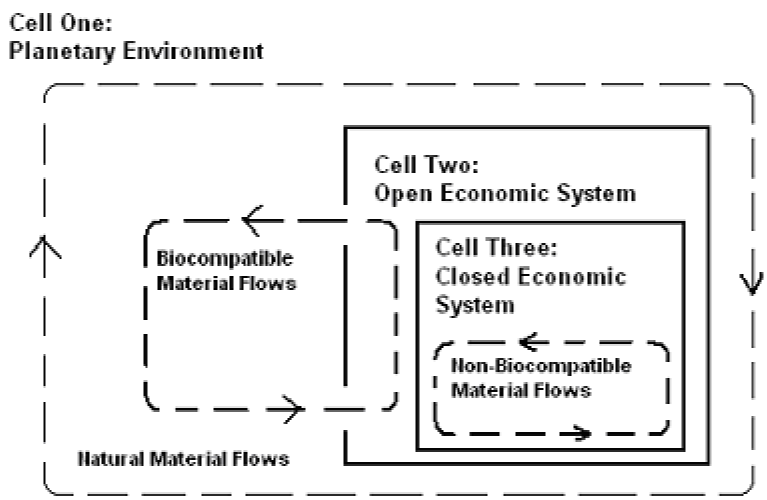


Figure 13. Materials Flow Model
Source: Geiser, 2001

In fact, in the existing industrial economy, the materials most likely to be continuously recycled—e.g. iron, copper, gold and silver—are among the least hazardous, while the most dangerous materials—like benzene, styrene, and halogenated hydrocarbons—are the least likely to be recycled (Geiser, 2001, p. 202). Environmental regulation in the industrialized countries has been based on determining "safe" exposures and limiting releases to the environment. Even in the rare cases where this approach makes sense, it is negated by economic growth. What is more appropriate is determining the right materials for the right situation, and making sure that no substances are used where they shouldn't be. Many forms of packaging, for example, are made of materials that will outlive the materials they are enclosing; to the degree that packaging is even needed in a rational world, most of it should be made of "biological nutrients" or what Hawken (1993, p. 67-69) has called "consumables", which can be composted. Clothing should also be compostable; something it can't be today because of the widespread use of toxic dyes. The sealed technical loops of more dangerous substances should, of course, become smaller and smaller, since eventually all materials will have to be returned to nature and we can never completely avoid accidental releases to the environment. In the case of many existing industrial materials that are both toxic and persistent, they should be banned or phased-out as soon as possible.

In Chapter VI, I will deal with product stewardship systems that can implement extended producer responsibility (EPR) that can create strong pressures for producers to make their products out of benign materials. Again, it is worth repeating that dematerialization and detoxification work hand-in-hand—because the task of detoxifying production is far easier when the absolute amount of materials circulating is reduced. The same EPR incentives that encourage design for disassembly and reuse also encourage the use of healthy materials.

Design Strategies for Clean Production

To be successful all green economic transformation strategies have to work on several levels. Green innovators have to pioneer cutting-edge alternatives that showcase the radical potentials of green production. But initiatives must also begin the process of incremental change in the mainstream.

Perhaps the most well-known radical example of benign materials production is that of Bill McDonough and Michael Braungart (2002) in creating a healthy and compostable upholstery fabric for an advanced eco-building in the US. Sixty chemical companies were approached, but only one, the Swiss Ciba-Geigy, accepted the challenge of collaborating with the project team. They considered more than 8,000 chemicals used in the textile industry and eliminated all but 38, from which an entire line of fabrics was created. Regulators testing the effluent from the mill found that the water leaving the plant was as clean as that coming into it.

Industrial ecologist Hardin Tibbs (1998, p.62) sees this as a pattern for future eco-manufacturing. The key, he writes,

> …would be first to identify a set of materials which have long-term geophysiological compatibility. A fairly small set of acceptable materials could probably be used to supply eighty percent or more of all production needs. The next step would be to devise clusters of production processes which use some or all these materials, and which can be interlocked ecosystem-style. Once this was done, the resulting industrial clusters or industrial ecosystems might stand a reasonable chance of being stable over time.

The kind of innovative cutting-edge work carried on by McDonough—one of the US's leading green architects and former Dean of the University of Virginia School of Architecture—and Braungart—a chemist and professor who developed Greenpeace-Germany's clean production strategies—is essential to tapping the potentials of green manufacturing. It is desirable to have such advanced high-profile projects in every region which can help set the design imagination free from conventional attitudes around development. But equally important are the wide range of more modest initiatives that can incrementally move mainstream industry along the path of clean production. There are a number of fronts where important progress is being made—in science and technology, in local economic development, in toxics use reduction and pollution prevention, and in community and workplace health and safety.

One kind of initiative that combines elements of all these fronts is toxics use reduction. The best known organization is the Toxics Use Reduction Institute (TURI), based at the University of Massachusetts-Lowell, and funded mainly by the state government and matching grants. Although partly driven by the state's progressive toxics use reduction legislation, the Institute is more focused on cooperation than on regulation. It acts as a consultant to industry managers for positive action in the design of products and production processes. Begun in the early nineties, by 1998 the use of some 190 toxic chemicals in Massachusetts industry had been reduced by 33 percent and the generation of toxic by-products had been cut nearly in half. An independent evaluation revealed that the state had saved money by this reduction, as totals costs amounted to $77 million and monetized benefits totalled $91 million (Geiser, 2001, 2002).

Unlike mainstream environmental initiatives, the Institute focuses on chemical use rather than chemical release. It uses five main techniques:

1. material substitution in the product: this includes use of water-based, rather than oil-based, paints; and zinc-plated rather than cadmium-plated products.
2. material substitution in the process: examples are replacing chlorinated solvents with aqueous cleaning systems; and replacing organic painting stripping with mechanical blasting.

3. improvements in production efficiencies: including installation of automated temperature or pressure controls to improve product yield; and replacing nozzles on paint application to eliminate waste.
4. improvements in process operations or maintenance: examples include replacing gaskets and valves to reduce emissions; and centralizing purchasing operations to reduce overpurchasing.
5. internal recycling or closed-loop processing: for example, claiming and reusing rinse water in metal plating; and reworking batch process by-products back into the next batch.

Among the many dimensions TURI integrates into its work is occupational health and safety. Amazingly, the situation of workers is often not taken into account when trying to eliminate toxic chemicals from the environment. (The same thing can be said about the impact on and participation of workers in eco-efficiency and conservation improvements in most cases). TURI planning and consultation puts these concerns front and centre. TURI is also concerned with creating an infrastructure for clean production that includes job training for workers, managers and designers, and connecting university research in key areas to managers and regulators. It also has a community component, acting as a clearinghouse of information about what communities can do, and are doing, about toxic chemicals.

TURI is an example of the potential role of universities in facilitating the transformation of green production. It parallels efforts in related areas like green chemistry (at. e.g., the University of Oregon), and eco-industrial development (University of Southern California, Lund University in Sweden, the University of Tennessee, and

RMIT University in Australia). TURI is also a university partner at UMass-Lowell with the Lowell Center for Sustainable Production, one of the world's most innovative green development programmes. Because of the knowledge-intensive basis of green production, universities must play a central role in economic conversion and the transformation of the professions.

The Carbohydrate Economy

An essential dimension of detoxifying production is increasing the use of renewable and bio-based materials that can be more safely reabsorbed by natural systems. The achievement of sustainability depends just a much on moving back (or ahead) to renewable sources of materials as it does on moving towards renewable sources of energy. By closing loops, renewable resources help dematerialize as well as detoxify the economy.

The current hegemony of non-renewable and synthetic materials in our current economy was established in a relatively short time frame. According to Tim Jackson (1996, p. 29), "In 1900, even after 150 years of industrialization, over half of the total materials in use (excluding those used for fuels and for foods) were still provided by agricultural, wildlife and forestry products." The earliest synthetic materials and plastics were derived from plant matter. Rayon, for example, was derived from cotton, and the first movie film—celluloid—came from cellulosic materials, as did the first "cellophane" tape. Even in the face of the growing power of the oil and auto industries, advocates for renewable resources remained influential. In the 1930s and early 1940s a strong movement emerged advocating the comprehensive use of agricultural materials for industrial uses. Led by US National Research Council chemist William J. Hale, the "Chemurgy" movement included many notable figures in American society including Thomas Edison and Henry Ford. It had widespread support among farmers hard-pressed by the Great Depression, and captured the attention of government for its wartime contributions to finding domestic substitutes for foreign materials (Finlay, 2004; Geiser, 2001; Morris, 1990).

The triumph of the petrochemical industry was, however, probably inevitable given the superior mobility of oil. Mobility was a decided asset for resources in 20th century industrial development which was based in giant economies of scale, mass markets and tendencies toward centralization. Oil also had an advantage in the ease in which industrial chemicals could be derived from petroleum in the cracking process (Morris & Ahmed, 1993).

Those advantages are today either fast evaporating or artificially reinforced. On one hand, efficient economies no longer prize mobility as essential and desirable. Flexibility is more valued than size, centralization and massive economies of scale. There is increasing public pressure on government to make industry internalize the formerly externalized costs of long-distance transport, making petrochemicals gradually more expensive. Using resources as close as possible to where they are produced is the ideal. Hemp, straw, soybeans and other renewable materials are not as easily transported as oil, but for this very reason they can be used as a means of local-regional development. They encourage local processing of locally-grown materials. The emerging Carbohydrate Economy is being heralded as a key component in a possible revitalization of rural communities (Osdoba, 2002). But it also features prominently into emerging visions of green cities that find positive local use for their massive organic wastes through rooftop gardens, urban agriculture, and even growing industrial feedstocks.

On the other hand, at the same time, developments in the life sciences and materials science are making it easier to use plant materials for a wide variety of uses in manufacturing and construction. In the last decade or so, we have seen an explosion in the commercialization of enzyme-based detergents, vegetable-based inks and paints, and starch-based plastics. Plant oils and resins are increasingly used in the production of lubricants, paints, detergents, solvents, and plastics. Wood, cotton, kenaf and hemp are used as a source of fibres. While there is growth in the use of traditional renewable materials like hemp and soybeans; there are also newer ag-based materials like rapeseed, (an oilseed with a wide variety of uses), quayule (a replacement for both natural and synthetic rubber); and jojoba (currently used in cosmetics, but with increasing uses in plastics, soaps and waxes). In addition, there has been a vast expansion of materials generated by biological processes like fermentation (Geiser, 2001, p. 286).

While the potential of biochemicals to displace petrochemicals is probably the most dramatic aspect of the Carbohydrate Economy, there are many other important applications for plant matter, particularly in building. Low THC-hemp is the best known example of a plant material which promises major dividends in displacing more destructive, less versatile and durable products (Hemptech, 1995). Every part of the hemp plant can be used for applications like building materials (fibreboard and insulation), clothing, food (cooking oils and spreads), and more.

Advocates for forest conservation also promote the industrial use of agricultural materials as an alternative to virgin wood fibres for both paper and building materials. In most cases, the production of pulp and industrial fibres from agricultural residues is less environmentally damaging than from virgin wood materials. Agricultural fibres are much more porous than wood, and have much lower lignin levels. Both of these factors make straw easier to pulp. Most agricultural fibres are shorter than softwood fibres, and are therefore well suited for the manufacture of certain specialty papers (Hayes, 1998).

Straw, a major agricultural waste product, is another material which is finding useful applications in building (Lorenz, 1995). Various kinds of sheetgoods are using straw as a primary component. And old-fashioned strawbale construction techniques are being revived as modern builders are finding it cheap, strong, durable, non-toxic and insulating (Steen, Steen, Bainbridge, & Eisenberg, 1994). [In Chapter V, I will look more closely at this use of straw in the movement for "natural building".] Similar ag-waste materials, like rice hulls, are being used in the production of composite outdoor lumber whose sales are booming with the phase-out of CCA-pressure-treated wood.

At the same time that the applications of plant materials are multiplying, their costs of production are decreasing. The cost of several industrial enzymes dropped by almost 90 percent from l980 to 1995 (Morris, 2002)—while the regulatory-imposed costs of synthetic hydrocarbon-based production continued to mount. Renewable materials tend to be more environmentally benign in all phases of their life cycle: extraction, processing, use and disposal. Most petrochemical processes, for example, employ large quantities of inorganic acids and bases, like sulphuric acid and sodium hydroxide, creating many toxic effluent streams. Globally, 40 percent of toxic pollution from manufacturing comes from the chemical industry (Jackson, 1996, p. 130). Concerns about environmental and human health have prompted bans and restrictions on substances like phosphates in detergents and synthetic dyes in food. Compared to biological processes used for creating plant-based products, chemical manufacturing processes for organic minerals are also far more energy-intensive, requiring high pressures and temperatures. Almost all bioprocesses occur at 30-40 degrees (Morris & Ahmed, 1993). On the disposal side, the growing cost of waste disposal, both conventional and toxic, makes renewable materials increasingly attractive since they are far more capable of being safely re-assimilated by natural systems. Until recently, many farmers disposed of agricultural wastes by burning or landfilling them. The burning of straw created 56,000 tons of carbon monoxide annually in California alone (Hayes, 1998). The use of agricultural waste as an industrial feedstock thus serves a double purpose—of reducing the cost of waste disposal and providing inexpensive materials for industry.

Another aspect of the Carbohydrate Economy are the contributions made by the life sciences in the realm of bio-based materials. These are not so much traditional renewable materials, but materials made possible by applying natural principles to production through processes like bioprocessing, biodegradation and biomimetics. Learning from nature is not new to science—quite the contrary, it was the foundation of science—but over the last 150 years a brute force approach to materials development, relying on heat, pressure and waste, has come to dominate. The bio-based materials revolution is, in a sense, the flip side of the same knowledge-base that is bringing us nightmares of imperialistic science in cloning and genetic engineering. But it is an expression of a more respectful attitude toward nature and ecological contexts.

Product	1996 production (millions tons/year)	Percent of total market, 1992	Percent of total market, 1996
Wall Paints	7.8	3.5	9.0
Specialty paints	2.4	2.0	4.5
Pigments	15.0	6.0	9.0
Dyes	4.5	6.0	15.0
Inks	3.5	7.0	16.0
Detergents	12.6	11.0	18.0
Surfactants	3.5	35.0	50.0
Adhesives	5.0	40.0	48.0
Plastics	30.0	1.8	4.3
Plasticizers	0.8	15.0	32.0
Acetic acid	2.3	17.5	28.0
Furfural	0.3	17.0	21.0
Fatty acids	2.5	40.0	55.0
Carbon black	1.5	12.0	19.0

Table 3. Industrial Materials Derived from Plant Matter
Source: Moser, 1998

Bioprocessing (sometimes called biosynthesis) is the making of materials from natural processes. It has a long human history, in the forms of brewing beer, making wine, culturing cheese and leavening bread. Scientific understanding of bioprocessing began with Pasteur in the 1870s, and beginning around 1900 experimentation began in the use of fermentation processes to produce industrial materials. The petrochemical boom in the postwar period brought these applications of microbiology to a standstill, but it has been steadily recovering over the past few decades. Fermentation is being used to produce a range of products from organic feedstocks (like ethanol and glycerol) to amino acids, enzymes, vitamins, antibiotics and single-cell proteins. While most of the applications are in pharmaceuticals and agriculture, there are increasing applications for industrial materials like acids and polymers (Geiser, 2001, p. 282-304).

Biodegradation is the opposite of biosynthesis, breaking down chemical and cellular structures. Safe biodegradability is essential to creating the closed loops of a green economy. One major application is, of course, the detoxification of human wastes, and experimentation with various forms of biodegradation has been taking place on the municipal level for decades. New concerns with water quality and with organic waste are driving new research and experimentation. Biodegradation is also finding uses in industry. It can be used to degrade inorganic ores to separate out desired materials. Such bacterial leaching processes require comparatively small energy inputs, and can be very handy for difficult-to-reach ores. Biodegradation also has applications in product design—e.g. in packaging where disposability is desirable—and for geo-textiles made to act as agricultural mulches.

Biomimetics is an emerging field in biology that focuses on studying and replicating the processes of living organisms, including the making of materials. It is a fertile ground for finding out how we can make things with less energy, less waste, stronger and compatible with surrounding contexts. One key area is that of protein-derived fibres like silk, wool and hair. Another area focuses on shells, bones and tusks—natural ceramics of great strength. Still another fertile area is adhesives—learning, for example, from the sea mussel who produces and cures an incredibly powerful adhesive completely underwater (Benyus, 1997, p. 118-125).

Challenges and Pitfalls of Plant-based Production

Despite the comparatively rapid growth of the Carbohydrate Economy, the petrochemical industry still occupies the core position within capitalist industrial production. Despite some regulatory pressure to internalize costs, it still continues to externalize costs while moving ever more deeply into new areas of production. Oil remains the life-blood of industrial capitalism, the beneficiary of massive subsidies, perhaps $20 billion per year in North America (Myers & Kent, 2001). Despite the emergence of the exciting new realm of green chemistry, comparatively few research resources are going into carbohydrate as opposed to conventional hydrocarbon chemistry. The portion of plant-based production in the industrial economy is still small. In the US, plant matter is estimated to provide about 1 percent of the country's transportation needs, 2 percent of its electricity needs, and 3 percent of its chemical needs (Morris, 2002). Manufacture of industrial and construction materials in US consumes about 175 million tons of petroleum and 300 million tons of inorganic metals each year, only 10 million tons of plant matter other than wood go into these products (Geiser, 2001, p. 259).

The potential is great however. The Institute for Local Self-Reliance estimates that available non-food growing lands, along with agricultural and urban wastes amounting to 300 million tons, could completely replace petrochemical with biochemical production in the US (Morris, 2002). Other researchers have argued that, even leaving half of agricultural residues on the fields for conservation purposes, the remaining residues could supply the US with between 70 and 175 million tons of pulp per year—more than is used annually by U.S. industries to produce paper. With manufacturers paying up to US$45 per ton for wheat straw, producers like Agriboard Industries claim that local farmers stand to make more from selling the wheat straw than from selling the actual crop (Hayes, 1998).

Realizing the potential of the Carbohydrate Economy depends, however, on many other changes. As with other aspects of green economic development—like solar energy and green taxation—some of its advocates reify its importance. But the Carbohydrate Economy is, by itself, no panacea. Without a fundamental redesign of the economy's basic structure and values, it can even present a barrier to sustainability. Here are a few important considerations:

Without a transformation of agriculture, industrial use of agricultural materials can simply intensify the mining of the soil, the destruction of both environment and rural communities, and actually reinforce oil-based development. Agriculture today is one of the most destructive and polluting of all industries. It depends on heavy capital investment and petrochemical inputs in the form of pesticides and fertilizers. It is also based on oil in the form of long-distance transport, with the average molecule of food travelling 2000 miles before being consumed. A healthy Carbohydrate Economy would increase the diversity and reduce the size of the typical farm; facilitate organic methods and the regionalization of agriculture; and make the most of agricultural waste. But large agribusiness interests like Cargill and Archer Daniels Midland (ADM) are promoting the appropriation of food lands for industrial crop monoculture utilizing conventional capital-intensive methods. Internationally, the pharmaceutical industry is a major player in the intensive exploitation of plant matter, especially in the South. In some cases it is working through international institutions like the World Bank and large ENGOs (like the WWF) to displace local cultivators from traditional agricultural practices to create "nature reserves" that can produce botanicals for world markets (Isla, 2000).

Another consideration about plant-based production is that, although biochemicals tend to be more benign than petrochemicals, they are not necessarily so. Biochemicals that are chemically identical to petrochemicals, and which do just as much damage, can be made. The impact of biochemicals depends on how the substitution is made. The most benign substitutions tend to be ones that use chemically dissimilar substances to achieve a similar purpose. A biochemical, for example, might be substituted for a petrochemical substance in a synthetic dye. Or, better, a completely natural plant-derived dye might be used. Or, most ecologically, a certain strain of coloured organic cotton could be used that makes any dye—natural or synthetic—unnecessary.

The proper development of bio-based materials depends on a non-exploitative attitude to nature. While the processes of biosynthesis, biodegradation and biomimetics have great ecological potential, they also have great potential for abuse—as is currently taking place in related forms of bioengineering like genetic engineering. Some of the earliest applications of biochemical fermentation were in explosives production. Bacterial leaching (biodegradation) is used in the mining industry. The U.S. Dept. of Defence and the auto industry are major supporters of biomimetic research into super-strong materials (Geiser, 2001, p. 290, 293). Thus many of these "end-uses" are questionable.

Perhaps most disturbing is the role of genetic engineering to manipulate natural processes in new and untried ways, unbounded by natural precedents, that threaten whole environments simply for the sake of profit. If the Carbohydrate Economy becomes a major market for genetically-modified plant species—as it already seems to be for GM-corn used for bioplastics production (Thorpe, 2003)—this presents a major obstacle to truly benign materials production.

Against the power of the large agribusiness and chemical companies, various organizations—like Greenpeace, Clean Production Action, and the Institute for Local Self-Reliance—are promoting a more holistic and ecological path for Carbohydrate Economy development. There are also eco-industrial development initiatives that are combining eco-industrial organization with plant-based production.

Some of the most interesting work is that of Gunter Pauli (1998) and his colleagues at the Zero Emissions Research Initiative (ZERI), based in Geneva and in Tokyo at the United Nations University. Pauli was previously founder and president of Ecover, the well-known environmental products company. He was suddenly faced with the realization that the soaps and cleansers his company produced, while slightly reducing pollution of German rivers, generated massive waste in Latin America—the source of Ecover's raw materials. Pauli saw the need—and the possibility—of producing plant-based benign materials through ecological "industrial clusters" which would make productive use of all materials, residues and by-products. He saw that, by applying an ecosystem approach that generated "value-added" on multiple levels, an "upsizing" process could be initiated which would provide benefits to all stakeholders, and not simply shareholders. ZERI has spawned a number of innovative projects in various parts of the world, including the Fujisawa Factory eco-industrial park in Japan (Cote & Cohen-

Rosenthal, 1998). Other ZERI projects exist in Canada, Namibia, Sweden, Fiji, Columbia and Benin (Zero Emissions Research Institute (ZERI), 2003).

Pauli puts great emphasis on making plantations, particularly in the tropics, into “biorefineries”. Currently most plantations are embodiments of monoculture, producing single products with massive volumes of waste. These same plantations could, however, provide vitamins, adhesives, oils, fibres, food, beer and much more from symbiotic processes which produce no harmful emissions. At the same time they can provide much of the planet’s necessary cellulose—from fast-growing crops like bamboo, sugar cane, rattan and oil palm—saving the wasteful use of trees like spruce, pine and fir. From serious carbon dioxide generators, they can become major carbon sinks.

The key to ZERI’s methodology is a creative output-input visioning process which can complement the traditional “pollution prevention” (P2) input-output methodology. That is, finding safe and productive uses for all outputs of a process can generate unpredictable benefits and “value added” far beyond the efficient use of existing inputs. But this requires broad knowledge and a desire to cooperate with other producers, community stakeholders, etc. in order to realize the optimal productivity of not just the firm, but of the surrounding community and ecosystem (Pauli, 1998).

The benefits of plant-based production can only be fully realized by the application of ecological design principles to production systems. As Tibbs argued above, a focus of green product stewardship would be to get the most out of a relatively small set of benign materials, using clusters of production that could be “interlocked ecosystem-style.” It is this collaborative organization that would allow the use of plant-based materials to almost completely detoxify the manufacturing process.

Strategic Issues in Building Materials Production I:
Engineered Wood Products

Having surveyed the general form and content of green production, it's time to turn our attention more specifically to building materials. While every category of building materials presents major challenges in implementing ecological production, I want to focus on a few key areas of strategic concern for green building. They include engineered wood products; the role of concrete and cement; the use of plastics, particularly PVC; and finally, the general issue of indoor air quality. (While the latter seems to be a question of building use, problems of indoor air quality must be ultimately resolved in the realm of production.)

The Carbohydrate Economy is one example of the positive application of advanced science and technology to ecological production. One might expect that another conceivable example might be that of advanced or engineered materials. Unfortunately, however, the thrust of mainstream "materials science" has been largely unconcerned with questions of human health or environmental sustainability. New "advanced materials" that exhibit superior strength, hardness, or other thermal, electrical, optical or chemical properties have been developed which have had a major impact on industries like communications, weapons, space travel and medical devices. They include metal alloys, structural ceramics, advanced polymers, and many kind of composites. But it is their characteristics and specialization that makes them advanced, not their sources, since they are largely made from conventional raw materials. Some have possible positive environmental applications—for example, the use of some alloys, super-polymers or various "smart materials" in facilitating energy-efficiency. But in most cases, the new materials are simply creating new problems in pollution-control, occupational health, and recycling (Geiser, 2001, p. 237-258)

Engineered wood products are one of the most important recent expressions of technology in building materials, and they have had a major impact on residential construction over the past twenty years. As cellulosic products, they constitute an important part of the Carbohydrate Economy. But while they are comprised of largely “renewable” materials, they are man-made, and so embody some of the most positive and negative aspects of industrial production. Although they do not really rate as “advanced” materials, they are quite different than traditional materials and they also environmentally outperform most of the so-called advanced materials. Engineered wood products have tremendous potential to become ecological materials by making the most of wood waste and wood by-products. Some of these engineered materials can dispense with wood altogether by replacing virgin wood fibre with agricultural residues. But this category of materials has some issues to resolve—particularly around wood certification and toxic binders—before these products can be unambiguously embraced as green materials.

The most significant use for engineered materials thus far has been for structural components like beams, joists, studs, and window and door frames; but there is growing use of engineered sheet goods for wallboard, subflooring and sheathing, as well as production of engineered products for siding, flooring and trim. Engineered materials—and engineered systems for floors and walls—have had a major impact on the way housing has been built over the past two decades (Gonzalez, 1999), and engineered wood is used in around 40 percent of homes built today in North America (Heavens, 2002).

Engineered structural materials use laminated wood chips or strands and fingerjointing (the gluing of larger pieces together). The use of small wood pieces or wood fibre drastically minimizes the amount of waste in creating structural products, and also makes more complete use of forest resources by the use of whole trees and a wider variety of species. Although more expensive than conventional wood products, engineered materials are stronger, sometimes lighter, dimensionally more stable and uniform, and also more predictable in price. They decrease pressure on old-growth forests by replacing conventional wood framing members like 2x10s and 2x12s that must be milled from wide diameter (18 in./460 mm.) trees. Because of their strength, they can usually be spaced farther apart than conventional wood members, saving even more material and offsetting any financial premium. Their strength also makes products like glulam beams and arches a substitute for steel.

In recent years, engineered wood products have appeared that are comprised of wood from FSC-certified forests making these products even more environmentally benign (1999, p. 6).

Glue-laminated timber (or glulam beams) were first used in Europe early last century, making their North American appearance in the mid thirties (Gibson, 2002). Wartime diversion of steel for military equipment spurred experimentation, and glulam production of (typically arched) beams for churches, warehouses, auditoriums, etc. took off after World War II (McNall & Fischetti, 1995). They paved the way for a wide variety of engineered structural materials that would eventually transform residential housing construction. The first widely-used residential product was Trus-Joist's I-beam, originally comprised of a vertical piece of plywood between two solid wood flanges in the shape of an "I". Its popularity (in the 1970s) was due to growing interest in "open plan" building designs that required long unsupported joist spans. I-joists are also very useful in framing cathedral ceilings (Fisette, 2000). By 1977, the Trus-joist's solid wood components were replaced with laminated veneer lumber (LVL), which looks like plywood but whose laminations run in the same direction. Around 1990, the joist's plywood web was replaced with oriented strand board (OSB). Today, I-joists have been joined by boards and beams of laminated strand lumber (LSL), glue laminated timber (glulams), parallel strand lumber (PSL), and laminated veneer lumber (LVL) for a wide variety of uses (Gibson, 2002).

Engineered sheet goods take one giant step farther down the road paved for them by plywood. Plywood is an assembly of alternating wood veneers that run perpendicular to each other, bonded with an adhesive. Originating in the 19^{th} century, its production grew slowly until World War I; increased in the twenties with its use in airplane and auto manufacture as well as building; and finally exploded during and after WW II (Jester, 1995). Especially in the early days, large diameter peeler logs—sometimes over 5 feet/1500mm. wide—were required. In the seventies, waferboard made its appearance, followed by oriented strand board (OSB) in the eighties. Both could be made from smaller trees of species of little commercial value. A weaker material, waferboard disappeared from the scene, but OSB has captured half of the North American market for structural panels and is still expanding it dominance (Wilson & Malin, 1999).

OSB is less expensive than plywood, more available, and stronger in shear because all the strands interlock. It is now more widely used than plywood in residential building—for sheathing, subflooring and many other uses, including engineered structural components.

Besides using chipped or stranded small-diameter trees as their wood source, engineered sheet goods can also incorporate recycled newsprint, agricultural waste, or recycled wood waste. Some contain recycled post-consumer paper, by-product gypsum and recovered gypsum, wood chips from "non-commercial" trees, and annually-renewable agricultural fibers. Examples include hardboard made from waste wood; wallboard made from perlite, gypsum, and recycled post-consumer newsprint; 100 percent recycled newsprint fiberboard; and fiberboard made from straw. At the cutting-edge of engineered sheet goods are those made from agricultural waste—like WheatBoard and Primeboard, made from wheat straw and bound with formaldehyde-free glues (Hayes, 1998).

Engineered wood siding and flooring and composite lumber are generally the newest and least familiar forms of wood products, but are gaining in popularity because of environmental considerations. Most of these materials bond wood or other kind of cellulose fibre into a specified shape. The most common kind of siding is 100 percent wood, made from planer shavings, sawdust or other wood by-products from sawmills. In the case of Southern pine, it is cooked under heat and pressure, and turned into a fibrous pulp that is then formed into a mat, trimmed and placed in a press. Under heat and pressure, the press's engraving plates produce one of a variety of surface textures, including wood grain and stucco. It is then cut into panels or lap siding and painted (Temple-Inland, 2003). The final product typically carries a 25-year warranty, is less energy-intensive than metal siding, and considerably less environmentally damaging than polyvinyl chloride (PVC).

Another engineered siding product is fibre-cement siding (like Hardieboard). In it, cellulose fibres are mixed with cement to form a dense, durable, fire-resistant surface that promises to take over a considerable portion of the housing market as the movement to ban PVC grows in strength (Wilson & Malin, 1997a). Fibre-cement is also finding growing use in the making of roof tiles. They can be moulded to look like shingles, slate or clay tile, but are far lighter than clay or slate, and they constitute a much more ecological choice than asphalt shingles, which are among the most damaging building materials in widespread use today.

The realm of engineered materials contains a spectrum of new products that defy easy categorization. Examples include the increasing varieties of "composite lumber", the most common of which combine recycled polymers with wood waste material. The most widely known is TREX, a composite lumber used for outdoor decking. It is considered an ecological product, both because it is a substitute for arsenic-treated wood and old-growth cedar and because of its use of recycled materials. It is a decking material, but it is not a proper structural material, although various other wood-plastic composites (like Nexwood, which combines recycled polymers with rice hulls) can be used for modest structural uses like posts and railings.

This sphere of new "composites" is a tricky area. Not all composites, even making use of recycled materials, are necessarily ecological. Many of them are more appropriately considered "wood-filled plastics" than engineered wood. Some plastic-wood composites use virgin PVC along with cellulosic material; and even many uses of "recycled" PVC are environmentally destructive because they ultimately support new PVC production (see section below on PVC). And many forms of composite materials cannot be satisfactorily recycled at the end of their product lifetime.

Leaving aside the plastic composites, the two principal issues concerning engineered wood are their fibre source and their binders. The use of small diameter trees and low-grade species like aspen, soft maple and yellow popular sounds good, but is not necessarily ecological in itself. Eco-foresters question, for example, whether the replacement of diverse hardwood forests with plantations devoted to aspen is a good thing. Being made of wood, engineered products should rightfully be certified in the same way other wood products are. Only in recent years, however, has green certification made inroads in engineered wood. In February 2003 the Composite Panel Association (CPA) rolled out an Environmentally Preferrable Product (EPP) program in order reduce the use of virgin timber in engineered wood products. Based on the U.S. EPA's Environmentally Preferable Purchasing program, CPA's specification is designed to ensure that EPP-certified products contain 100 percent recycled or recovered wood fiber. Certified products must also meet the standards set for formaldehyde emissions by the American National Standards Institute (ANSI) (Boehland, 2003). Nevertheless, as of early 2005, the Environmental Building News' (2005) *Green Spec* catalogue was listing only five sets of recommended products (some sets containing different dimension lumber of the same material) .

The other major Achilles Heel of engineered wood is the glues or binders used to hold the material together. They can be environmentally damaging in production, the source of toxic emissions in use, as well as a waste disposal problem. Air emissions of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) contribute to a variety of modern maladies from smog to "sick building syndrome." The binders used in engineered wood, plywood and particleboard are usually either urea- or phenol-formaldehyde or resorcinol formaldehyde. Formaldehyde causes irritation and allergencity, and is a probable human carcinogen. Phenol is caustic and can harm the nervous system (Demkin, 1998, p. 639, 643).

New chemicals and processes are being used to reduce the VOC level of adhesives. These include new petrochemicals like methylene diphenylisocyanate (or MDI) or fast-curing phenolic resins (Reuters, 2000). But the most encouraging developments are emerging from other areas of green chemistry and the Carbohydrate Economy. On one hand, there is a resurgence of plant-based materials like soy as the raw material for newer safer adhesives (Hardin, 2000; Schmitt, 2002). Current research is focusing on concentrating on soy-hydrolyzate and soy-flour adhesives that can either displace or greatly reduce the use of formaldehyde resins in adhesives. On the other hand, European "bioprocessing" initiatives are experimenting with "nature's own glue"—enzymes—in bonding wood fibres. A partnership of government and private firms in Europe has had great success in producing Medium Density Fibreboard (MDF) with the enzyme laccase (Danish Environmental Protection Agency, 1999). Other breakthroughs in the reaction of tannins and crosslinking agents has produced more ecological OSB panels. Most of these developments still have some ways to go to establish mass production, but it may be just a matter of time before the problem of adhesives is fully resolved—especially with a little regulatory pressure.

By and large, engineered wood products have great promise as green materials. This promise is, however, still unrealized. How quickly it can be fulfilled depends very much on whether the green building movement—and attendant building and product assessment programmes—can continue to grow at the rapid rate of the last several years. The market demand of progressive builders and designers is crucial. Conversely, engineered wood is a product area that progressives may want to target as a fast route to more ecological building.

Strategic Issues in Building Materials Production II:
Cement and Concrete

Concrete is an ancient building material, used by the Romans for many of their great roads, buildings and aqueducts. But, except for perhaps the steel used for modern skyscrapers, no other material has so personified the industrial-era built environment as has concrete—with artists and musicians assailing the twentieth century capitalist city as a "concrete jungle". Concrete is the most widely used construction material in the world, with Canadians using about 10 kg per person per day (Ridsdale, 1998). One might justifiably expect that the evolving green building movement would, at very least, have to come to terms with—and redefine the use of—this omnipresent material.

More generally, alternatives to the "concrete jungle" cover the wide range of green materials—and relationships—covered in this dissertation. This section, however, will survey more specific alternatives to concrete use, as well as some the ways that concrete itself is being transformed to become a more ecological material.

Concrete is essentially a mixture of cement, sand, gravel and water. Properly mixed and installed, it is a strong, durable, and pest-and fire-resistant material. It is also a versatile material whose many forms include structural blocks; ornamental imitation stone; precast beams, piles and roof tiles; and poured-in-place reinforced concrete. It is this latter combination of metal bars (primarily steel) and concrete in reinforced concrete that has most shaped the industrial landscape in the form of skyscrapers, bridges, dams and highways.

Environmentally, concrete can offer some advantages, because of its durability and its capacity for heat storage in solar buildings. But, as it is conventionally produced and used today, it is a destructive material, primarily because of the energy-intensity of Portland cement, which constitutes about 12 percent of most concrete. For every ton of Portland cement produced, approximately a ton of CO2 is added to the atmosphere. The cement industry is one of the top two manufacturing industry sources of carbon dioxide emissions, in itself generating about 8 percent of the world's CO2 emissions (Mehta, 1998b; van Oss & Padovani, 2002). The CO2 emissions embodied in an average size North American house is roughly equivalent to 100,000 vehicle miles driven (Shell, 1998). There are other problems, notably in dust generation (in cement production and transport) and water pollution (in the ready-mix concrete industry). Emissions from cement production include sulfur dioxide (SO_2) and nitrous oxides (NO_x). Cement production is also responsible for an estimated 4 percent of US dioxin emissions. And in the mid-nineties, it was estimated that concrete represented 67 percent by weight and 53 percent by volume of construction and demolition (C&D) waste, with only 5 percent being recycled (Demkin, 1998). These local problems pale in comparison, however, to the impact on global ecological balances caused by the industry's massive energy consumption. When we include fuel use for mining and raw material transport, cement production takes about 6.3 gigajoules (six million Btus) for every ton of cement. This makes cement production approximately ten times as energy-intensive as the North American economy. In some Third World countries, cement production accounts for as much as two-thirds of total energy use (Wilson, 1993). This is particularly disturbing when one considers that, because of the development needs of Third World, the demand for Portland cement in the world is projected to double in the next few decades (Mehta, 1998a).

Ecological solutions for concrete problems involve changes in production. But perhaps the most influential decisions are those of building designers and developers in selecting materials. They can affect what and how things are produced. There are four main strategic foci for the green building movement: first, finding *alternatives to concrete*; second, when its use is appropriate, *designing to use less* of it; third, *using more ecological concrete* that contains substantially less Portland cement; and lastly, finding ways to *recycle C&D concrete*, and designing concrete materials for reuse. In this brief overview, I can only touch on key examples of each focus.

The principal means of ***replacing concrete*** is clearly the use of steel. Life cycle comparisons of steel and concrete over the last decade have indicated that steel may be the more appropriate choice for many structural applications. Germany's Wuppertal Institute compared the use of steel and concrete for pylons, bridges and similar structures in the OECD countries. Using the MIPS concept—"material input per service function"—it found that a threefold improvement in material efficiency could be gained by a switch from concrete to steel (Sachs, Loske, Linz, & et al, 1998, p. 106-107). This could easily be increased to a sixfold improvement if scrap iron and steel were used, and these numbers could be further improved if newer electric steel smelting methods replaced traditional oxygenation methods. An interesting sidebar to these findings were the insights of the Wuppertal research committee about the increasing market dominance of concrete over steel in construction after WWII. They found that it had little to do with costs, and much more with engineering fashion—concrete being seen as more modern and elegant (von Weizsacker, Lovins, & Lovins, 1997, p. 78-79).

A number of life cycle assessments comparing steel and concrete for specific buildings have also been done. Massachusetts Institute of Technology (MIT) undertook such a study (as part of a general environmental assessment) for its East Campus Project, a proposed 450,000 square foot building complex in Cambridge Massachusetts. It compared models for steel and reinforced concrete superstructures in eleven categories: energy consumption; natural resource use; toxics use; transportation of materials; solid waste production; recyclability of materials; air pollution emissions; water pollution emissions; global warming potential; and two occupational health categories: fatal and non-fatal injuries and illnesses. Results showed steel superior in seven of the eleven categories. The only impact category where concrete was clearly preferable was water pollution, due to the large amount of water used in steel-making processes for cooling, quenching, and pollution control and the greater abundance of toxic chemicals used in steel making. In the natural resources category, it found that concrete would use almost six times as many raw materials as steel (MIT East Campus Project team, 2002).

Steel is not always an appropriate substitute for concrete however, and some of the most imaginative contributions of the green building movement have been in finding ways to ***reduce concrete use***, our second main strategy to mitigate concrete's environmental impact. Concrete is an excellent foundation material, for example, but it can be used more intelligently for major material savings. The typical North American home uses nearly 14 tons of concrete in its construction (Loken, 2002a), but much less might be used to better effect.

One strategy is pier foundations, using reinforced concrete piers, formed by construction tubes made from recycled paper (like Sonotubes), in conjunction with recycled-plastic or fabric footings. While they are currently used more often for decks, they have great potential for buildings, particularly on ecologically fragile sites. Another strategy is foundation insulation placed to insulate the surrounding soil, thereby reducing frost depth of the soil and the required depth of the footings. Another possibility is "slab on grade" or floating slab construction that in most cases will reduce the amount of concrete by eliminating foundation walls. Still another is engineered thin-wall foundations—150 rather than 200 mm. (six rather than eight inches) thick, a strategy developed in Canada (Loken, 2002a).

A major way to reduce concrete use is to utilize precast rather than poured concrete. Using precast can substantially reduce waste, as material quantities can be more precisely estimated and excess material can be reused. Higher strengths are also possible, consistency increased and insulation can be built into many precast systems. The Waterloo Ontario Green Home, one of Canada's pre-eminent Advanced Houses, built in the early nineties, featured precast concrete foundation walls in the form of 8 foot x 16 foot panels. They were smooth on the outside, but waffle-ribbed on the inside, using 50 percent less concrete than the normal wall, and placed on 6-inch thick pads, 3 foot square, at each end of the panels (Grady, 1993). Superior Walls is another US precast system that uses only a third of the typical concrete wall (Wilson, 1993); it is also built with rigid insulation formed right into the panels. Superior has 23 franchises in 18 states (Superior Walls of America Ltd., 2003).

Another increasingly popular way of conserving concrete is the use of block and form products that not only use less concrete but in most cases actually increase the insulating value of foundations. This is important since regular concrete is a poor insulator. Among these materials, the oldest is Durisol, first manufactured in Europe in the forties and here in Ontario beginning in the fifties. It is basically a fibre-cement product—a concrete made with Portland cement but with mineralized wood shavings as the aggregate, instead of sand and stone. The mixture is used to make stay-in-place wall forms for concrete structures, and strong but lightweight blocks for sound barriers, retaining walls, and other uses. The blocks are laid up without mortar, rebar is inserted in the hollow cores and concrete is poured in. There are mineral wool insulating inserts for the form panels. The Durisol wall is strong, insulating; rot-, fire- and pest-resistant; non-combustible; uses waste wood materials; and is environmentally benign. It is quite popular for high-rise construction for its economy as well as its sound-proofing qualities (*Durisol Industries*, 2003). It has spurred a number of imitators with varying ingredients and characteristics. Other kinds of insulating foundation systems (IFS) exist that can reduce concrete use but are designed primarily to insulate. As with Durisol, they are mixtures of cement, with either wood waste or foam (usually expanded polystyrene, EPS), where concrete is poured into the cores. They come in different configurations, use different connectors, and achieve varying R-values. Some of the forms may not directly reduce concrete use, but they definitely increase its thermal efficiency and longevity .

Finally, although a comprehensive discussion of the impact of land use planning on materials consumption is beyond the scope of this dissertation, our discussion of concrete reduction strategies must at least mention that a green economy means many fewer highways. A shift away from large loops of production and consumption requires more compact development patterns with mixed commercial, residential and even industrial uses. About 40 percent of the surface area of North American cities is currently highways, parking lots, etc., and much of this area can and must be taken over by green space. This means both a drastic reduction in concrete and asphalt use, as well as the substitution of new kinds of "porous paving" (Environmenal Building News, 1999).

The third strategy for reducing the environmental impact of concrete is ***transforming its composition***, primarily by reducing its cement content. As discussed above, it is the energy-intensity of cement that is the most problematic aspect of concrete. The primary means of achieving cement reduction is the substitution of waste flyash for Portland cement.

Flyash is a waste by-product from coal-fired power plants. It is a pozzolanic material, very much like the pozzolan clay, created by volcanic activity, used by the Romans in their early forms of concrete. The US produces about 60 million tons of flyash a year, with about 75 percent of it landfilled—basically 26 cubic miles (Mehta, 1998b). Flyash can substitute for up to 60 percent in a concrete mixture, and sometimes even more, depending on the application. Various studies have demonstrated that replacing 25% of the cement in concrete with fly-ash reduces energy consumption by 8.7%. This increase from the present 9% fly-ash would save 79 million MJ of energy in the U.S. alone (Glover, 2001).

Flyash affects the plastic properties of concrete by improving workability, reducing water demand, reducing segregation and bleeding, and lowering heat of hydration. It increases concrete strength, reduces permeability, reduces corrosion of reinforcing steel, increases sulphate resistance, and reduces alkali-aggregate reaction. In short, it not only pays economic and environmental benefits, but it also improves the quality of concrete. It's only real drawback is a slightly slower setting time.

Flyash concrete has been catching on with the rapid growth of the green building movement in the past several years. Nevertheless, it is still the object of negative bias by the mainstream building establishment. Part of the bias is due to sheer ignorance and the old view that it is dilute concrete. Part of it is that conventional practices change slowly in building, and the slightly longer curing time requires changes in scheduling. Studies and experimentation—along with builders' direct experience of higher quality—are quickly breaking down these biases, and in fact, experimentation is growing with other cement substitutes like steel slag and rice hulls.

There are certainly other measures that can be taken to reduce the energy-intensity and CO_2 emissions of concrete, particularly those that improve of the efficiency of cement kiln operation. These include switching to lower-CO_2 fuels such as natural gas and agricultural waste, and using waste lime from other industries in the kiln (Wilson, 1993). But the substitution of flyash and similar materials for cement is the main way to reduce the environmental impact of concrete that needs to be used. When combined with measure to reduce the amount of concrete, described above, using more ecological forms of concrete can produce major dividends in quality building and drastically reduced carbon emissions.

Recycling is the final strategy for reducing concrete's environmental impact. Concrete can be recycled, but a lot of it isn't. Currently about 10 percent is recycled in Europe and less than 5 percent in North America. Construction and demolition (C&D) waste, which will be dealt with more generally in the next chapter, is anywhere from a quarter to a third of municipal waste, and concrete and masonry rubble is estimated to be about half of that (Demkin, 1998; U.S. Environmental Protection Agency, 1998). Concrete that is recycled tends to be "downcycled" into lower-level uses like base materials for roads and footings, drainage material around underground pipes, and landscaping materials, etc. As aggregate for new concrete, it is usually mixed with a certain proportion of virgin stone. How much concrete can be recycled depends somewhat on the application. Costs vary, depending on the costs of demolition, transportation and grinding as compared to available new materials. In many cases, where transport costs are low, and the material is used for road beds, using recycled concrete can be particularly economic. In the case of road replacement, machines exist that can process concrete from the old highway into aggregate for the new road base.

This kind of recycling is, however, a far cry from the closed loops of an ecological economy. Establishing such loops involves a focus on deconstruction rather than demolition, where construction and even manufacturing processes are designed with recycling and reuse in mind. One step in this direction is the establishment of four streams within the concrete-masonry category of demolition:

1. undiluted concrete rubble: which is thermally treated, producing gravel, sand and cement stone, with some steel.
2. undiluted masonry rubble: which is thermally treated, yielding mortar, bricks and brick pieces.
3. the mixed stony fraction, consisting of concrete rubble and masonry rubble of ceramic bricks and sand-limestone bricks. Decontaminated granules are obtained, used as coarse aggregate for concrete, fine fraction for a sand substitute, with only a small sludge fraction to be disposed of.
4. Mixed C&D waste: demolition waste not separated at source is sorted in an additional process. Gypsum and hazardous materials are separated by advanced detection and separation techniques. The hazardous wastes have to be disposed of; the gypsum recycled. The remaining material is divided into a heavy stony fraction and a light combustible fraction. The stony fraction is treated with the mixed rubble, The combustible fraction is reprocessed to obtain a fuel for the thermal processing plants.

These steps move concrete and masonry from waste management to chain management, making more comprehensive recycling of both possible (Mulder, 2000).

A basic problem in recycling concrete is its contamination with plaster, masonry and other materials, since many have very different densities and service lifetimes, and they may also affect the aggregate size and shape. Separating materials during deconstruction (and even in the building process) is crucial for materials efficiency. But even the design of concrete mixes (particularly the size of aggregates) can influence the eventual recyclability of concrete. Three principles can facilitate more comprehensive recycling: (1) reduce the variety of constituent materials; (2) avoid composites that are difficult to dissolve in construction, and (3) separate units and materials with different service lives & recycling techniques. Because the composition of concrete mixes can vary considerably, maintaining a careful record of material constituents—as a part of a general "passport for buildings"—can be invaluable when it comes time for replacing the building (Müller, 1999). These principles and strategies become even more important when we acknowledge that in a green economy, there will be many fewer roads built, and that more and more material loops will be geared to recycling—as opposed to ***down***cycling. I will explore these relationships more thoroughly as they apply to the recycling of all building materials in the next chapter.

Strategic Issues in Building Materials Production III:
Plastics in Construction

While concrete may be the icon of the industrial built-environment, it is plastic which is the pre-eminent symbol of modern industrial production. As such, plastics are inextricably a major part of the contemporary capitalist building industry.

Nature produces plastics—natural polymers like animal horn, tortoise shell, natural shellac—but there is certainly no material that represents the "man-made" economy more than plastic. Plastics are at the centre of the petrochemical industry, and petrochemicals are the core of manufacturing based on fossil fuels. Not only are its feedstocks oil-based, but the petrochemical industry also uses substantial amounts of energy—about 10 percent of all fossil fuels use. Petrochemicals are estimated to be responsible for about 40 percent of the world's pollution (Jackson, 1996, p. 30), and plastics are about 10 percent by weight of North America's solid and municipal waste. While many areas of petrochemical industry have stagnated, plastics remain a growth area—with an increase of 6.4 percent a year from 1995 to 1999 (Wilson & Yost, 2001b). They continue to replace not just traditional materials but also newer metals (Geiser, 2001, p. 53). 85 billion pounds of plastics were produced in 2000, with 60,000 compounds in production.

The iconic status of plastic is well-deserved. Plastics are the product of organic chemistry—i.e. the chemistry of carbon compounds that has thoroughly transformed the material basis of human society. It has created a new generation of materials that are unprecedented contributions to the human experience. It is this uniqueness that is the source of plastics' ambiguous social and environmental status. Whereas biological organisms use enzymes to assemble complex molecules (including natural polymers), the chemical industry uses catalysts to produce its synthetic polymers. Because the chemical bonds are different, natural organisms find it very difficult to break down these new compounds. Thus, plastics are among the most durable materials, but for similar reasons among the most destructive, persisting in landfills or releasing toxic substances in incineration. Besides the obvious disposal problems caused, these synthetic compounds create a whole host of debilitating effects in their production and use as well.

Plastics play a major role in building. Next to packaging, the construction industry is the second biggest consumer of plastics, representing 22 percent of plastic resin sales. The positive contribution of plastics cannot be denied: they offer relatively durable low-maintenance products; their light weight reduces shipping energy; foamed plastics are typically the insulations with the highest R-value; plastic caulks, foams, and housewraps are crucial in sealing buildings; plastic resins are used in engineered wood; and plastic wood helps displace old-growth and arsenic-treated wood.

But they have their down-sides, negatives on the environmental scorecard. the first plastics were plant-based, with Celluloid first patented in 1870. The first synthetic polymer—Bakelite—was invented in 1907, however, and over the next 40 years, plastics became ever more associated with the oil economy, inextricably connected with a corporatization of economic life (Fenichell, 1996). They became, in Geiser's (2001. p. 45) words, the "flagship material" of the postwar Consumer economy, structured by the suburb and the automobile. Their light weight was geared to extend production and consumption loops, and their inexpensiveness hid other environmental costs not registered by the market. These include the production—intentional or otherwise—of some of the most toxic materials ever seen. Many of these chemicals have been dangerous for workers to produce, and impossible to isolate completely from the community and environment throughout their life-cycles. To name just a few: vinyl chloride monomer and benzene are known carcinogens. Styrene is a suspected carcinogen; the plasticizers, especially phthalates, are likely both carcinogenic and hormone-disrupting; formaldehyde is a suspected carcinogen. And foamed insulations are the source of ozone-depleting HCFCs.

In use, all too many construction plastics are toxic in application and outgas harmful vapours, a topic I will deal with more extensively in the next section on indoor air quality. In disposal, these plastics present a major problem, with the recycling rate for construction being even lower than the low 6-7 percent rate for all plastics. There are some major technical problems in recycling plastics, especially composite materials. But even where recycling is technically feasible, there have been substantial collection and separation problems to inhibit it. And almost invariably plastics recycling is downcycling.

While it is important to understand the common attributes and problems of oil-based plastics, it is equally important to understand that there are important differences between plastics, and that plastics can have a role in an ecological economy. PVC, however, would not be one of those plastics. Because, as a chlorinated compound, it is considered the most destructive plastic, it is a particular target of the green building and environmental toxics movements, the object of a worldwide campaign to have it banned. Despite its negative impacts, however, such a phase-out is not a straightforward matter since powerful vested interests are arrayed in its defense. Because vinyl is at the nexus of major struggle by and within the green building movement, and also because this strategic position within the petrochemical economy, it is worthwhile to devote some attention here to the “PVC issue”.

PVC (or vinyl) is the only major building material that is an organochlorine, a class of chemicals that has come under increasing scientific and regulatory scrutiny over the last 15 years. An organic compound is a chemical built up around a chain of carbon atoms. Along this carbon skeleton, oxygen and hydrogen atoms are usually arrayed, along with, in the case of organochlorines, chlorine. Chlorine allows chemists to attach all kinds of other atoms to this skeleton, affecting for example the chemical's toxicity (desirable for pesticides) and solubility (desirable for solvents and plasticizers). But besides being industrially useful, such a chemical also tends to be persistent, bioaccumulative, chronically toxic, and frequently quite unpredictable. All of the "dirty dozen" of internationally banned persistent organic pollutants (POPs)—including DDT, PCBs and dioxin—are organochlorines. The problems with organochlorines are so systemic that many scientists and activists have called for the abandonment of case-by-case regulation of chemicals in favour of the phase-out of organochlorines as a class. This includes even the International Joint Commission on the Great Lakes, which saw organochlorines as the source of most of the lakes' most serious environmental problems (Commoner, 1992). Numerous European countries have banned PVC for certain uses, and the worldwide green building movement has made total phase-out a top priority for eco-building.

Some other classes of synthetic chemicals might also turn out to be as destructive as organochlorines, but organochlorines are the most pervasive chemicals in our chemicalized world, numbering over 11,000 in everyday commerce. In the words of W. Joseph Stearns, former Director of Chlorine Issues for Dow Chemical, chlorine has become "the single most important ingredient in modern [industrial] chemistry" (McGinn, 2000, p. 14).

PVC is the single largest use of chlorine, consuming about 40 percent of total chlorine production, or approximately 16 million tons of chlorine per year worldwide. It is the second most common plastic and the most used plastic in construction. While it is relatively inert in its useable form, PVC produces dangerous by-products at every stage of its manufacture; its feedstocks—ethylene dichloride (EDC) and vinyl chloride monomer (VCM)—are carcinogenic; vinyl creates indoor air quality problems in its use phase; and it constitutes a toxic time bomb for disposal. The sum total of its toxic releases over its life-cycle makes PVC responsible for more dioxin emissions than any other single product (Thornton, 1999). And, according to the European Commission, 1 kg of PVC generates 1 kg or more hazardous wastes (Thorpe, 2003). Besides all the problems with PVC in itself, its additives are also problematic. Pure PVC is too brittle to be used without a variety of additives. Heavy metals like lead are often found in stabilizers; but the overwhelming majority of additives are plasticizers, a class of compounds called ***phthalates*** that have been linked to a range of reproductive health effects, including reduced fertility, miscarriage, birth defects, abnormal sperm counts, and testicular damage, as well as to liver and kidney cancer. Phthalates have become almost as big a health concern as PVC itself. In summary, PVC (including its feedstocks, additives and unintentional by-products) has been associated with cancer, disruption of the endocrine system, reproductive impairment, impaired child development and birth defects, neurotoxicity (damage to the brain or its function), and immune system suppression (Thornton, 2000).

The PVC disposal time bomb is particularly disturbing. In the European Union alone, PVC waste is projected to increase 76 percent in the next two decades, to over 7 million tons in 2020 (Belliveau & Lester, 2004). None of the disposal options—landfilling, incineration or recycling—is satisfactory. Because of so many additives, PVC is difficult or impossible to recycle. If collected with other plastics, separation must be virtually perfect since even a small amount of PVC contaminates other more recyclable plastics like PET. PVC that can be recycled is invariably low quality, suitable for only the lowest grade uses like park benches. In the United States and Canada, just 0.1 percent of post-consumer PVC is now recycled. In the European Union, the figure stands at 3 percent (McGinn, 2000, p. 54). In the face of the coming avalanche of PVC waste, the highest possible percentage for PVC recycling projected for 2020 is 18 percent. Dumping PVC also creates problems, leaching out chlorine and phthalate additives, and contaminating groundwater. Even in high-tech landfills, PVC will tend to outlast the materials used to construct leachate collection systems.

Incineration is the worst disposal option, since PVC burning almost inevitably means dioxin creation. Medical and municipal incineration accounts for 69 percent of known dioxin and furan releases into the atmosphere—some 7,000 kilograms a year—and at least half of this is due to PVC (Ackerman, 2002). These same poisons are released by accidental fires, which, not incidentally, constitute an unprecedented occupational hazard for firefighters today.

Despite the ubiquitousness of vinyl in modern society, it is important to recognize that it dominance has been achieved more because of its profitability than because of its usefulness. While its wartime role in replacing rubber (primarily for wire insulation) helped jumpstart mass production (McGinn, 2000; Thornton, 2000), the PVC industry really originated in the need for the petrochemical industry to find a use for a troublesome toxic waste product of alkali and caustic soda production: chlorine gas. As Commoner (1990; 1992) and others have emphasized, vinyl has grown by displacing existing less toxic products that served fairly well in meeting people’s needs. PVC products have invariably been cheap, giving them a competitive advantage—but only because vinyl's massive environmental and health costs have been externalized into the community.

Vinyl's dominance in construction today has created the impression that using alternatives to PVC would be an expensive proposition. But the movements for green building and clean production have increasingly demonstrated that PVC-free building can be both high quality and cost-effective. The Tellus Institute's examination of the major studies on costs of vinyl replacement concluded that, using conventional construction designs and techniques, going PVC-free would increase average costs by only about $1.00 per pound for non-pipe applications. While an earlier study put the cost of pipe replacement as high as $1.40 per pound, the most recent and comprehensive study put the incremental cost of non-PVC pipes at only $0.15 per pound of PVC replaced (Ackerman, 2002).

The 2000 Summer Olympic Games in Sydney were a testament to the possibility of substitution for PVC. PVC was completely avoided in the Sydney 2000 Olympic stadium seating and plumbing; and the multi-use arena had no PVC in the seating, cabling, floor coverings, wall finishes or plumbing. Greenpeace Australia (Greenpeace Australia, 2003) took the occasion to set up an Internet database of PVC alternatives which is regionalized for use in various parts of the world.

The average designer or contractor however will find it easier to go PVC-free in certain material categories than others. Of the four key areas—roofing, flooring, siding and plumbing—alternatives in roofing and flooring are readily found, are competitive, and are in fact an upgrade in quality. Even apart from higher-end substitutes for vinyl flooring like ceramic tile and hardwood flooring, there are medium price alternatives like natural linoleum, cork and new resilient flooring materials like Stratica—which uses high-tech engineering polymer resins to provide a durable surface and sophisticated patterns similar to high-end vinyl, without the chlorine (Environmental Building News, 1998). A range of roofing materials are available, including non-chlorinated polymers like EPDM and TPO (thermoplastic olefin) single-ply roofing systems that actually outperform PVC. An increasing variety of materials are available, including recycled steel tiles and recycled rubber/polymer composites like Authentic Roof that look like slate but at 25 percent the weight of slate. Another example is Progress Roofing manufactured by Inteq Corporation in simulated slate, wood shake, and terra cotta tile profiles from 100 percent recycled HDPE. All three styles have uniform color throughout and come with a 50-year warranty.

Going PVC-free may be a little more difficult in the area of siding. Vinyl has now almost completely eliminated aluminum siding from the mainstream residential building market. Outside piping, siding is the biggest volume use of PVC in construction, representing about 15 percent of all new vinyl. The great appeal of vinyl is that it is "maintenance free". New forms of engineered wood paneling hold some promise, but more likely it is fibre-cement products, like those produced by James Hardie Company—including Hardiplank lap siding and Hardie Shingleside—that will offer the stiffest competition to vinyl in the maintenance-free siding market (Environmental Building News, 2005; Greenpeace, 2003). The main environmental problem with fibre-cement is its silica dust which can be a source of silicosis for manufacturing and installation workers . If this problem can be solved, fibre-cement seems to be the major green alternative to PVC for affordable mass-produced siding.

Another challenging area for substitution is piping—including tubing, conduits, and pipe fittings—which accounts for almost half of PVC sales. Most of this consists of municipal water and sewer pipes, outdoor drainage pipes, and industrial and agricultural pipes. Two types of PVC pipes are everyday residential construction materials: the DWV (drain/waste/vent) plumbing inside buildings, where use of PVC has become the norm; and electrical conduits, where PVC competes with steel. As in the case of siding, there are high-quality alternatives, but they are not so widely available as the mass-produced vinyl pipes. Clay pipe is more than suitable for underground sewage and water pipes, with a common life span of 100 years and a high resistance to chemicals in wastewater. In the UK, high density polyethylene (HDPE) pipes have been found to be more flexible and shock-resistant (Greenpeace Australia, 2003). Both polyethylene and metal pipe can be used in DWV applications—with Philadelphia's Sheraton Rittenhouse hotel (billed as North America's first eco-smart hotel) using black metal drainpipe for approximately the same cost as PVC (Ackerman, 2002).

Economic strategies for PVC substitution involve two key interrelated dimensions: (1) ramping up market demand for safe alternatives that can increase economies of scale and therefore decrease production costs, and (2) implementing various forms of extended producer responsibility (EPR) that reflect the full lifecycle environmental costs of PVC production. Because of the fundamentally unstable nature of PVC and organochlorines, real EPR should ultimately mean the complete banning of

PVC. But in the transition, other mechanisms like green taxation can be useful in forcing the vinyl industry to internalize its costs, thus levelling the playing field for alternatives.

The movement to ban PVC is already quite strong in Europe, where local and regional PVC-free policies have been implemented in Denmark, Sweden, Germany, the Netherlands, United Kingdom, Spain, Luxembourg, and Austria. Denmark, Sweden and the Netherlands have restrictive policies at the national level. Anti-PVC (governmental) procurement guidelines exist in Austria, Netherlands, Nordic countries, UK, Japan and even USA. Such community and regulatory action has spurred corporations themselves to replace PVC in their production processes, with Ford, Peugeot, Daimler Benz, Opel, Volkswagen, BMW, Mercedes Benz, Mitsubishi, Nissan, Toyota all adopting PVC restrictions (Thorpe, 2003). Nike has begun working with McDonough and Braungart to phase PVC out of its shoe-making operations (McDonough & Braungart, 2002).

In North America, the movement to phase-out PVC lags behind Europe but is growing in tandem with an exploding green building movement. I have already mentioned the initiatives of McDonough and Braungart, and of the Philadelphia Sheraton Rittenhouse, but there are many more. The Healthy Building Network, the coalition most responsible for the recent US residential ban of CCA-treated wood, is at the centre of the national campaign against PVC. But the campaign is affecting the rapidly spreading LEED building assessment programme of the US Green Building Council (USGBC) which now includes many federal, state and even military buildings. The cities of Seattle and San Francisco, and Boston have implemented various kinds of policy to reduce vinyl use, and developments in Europe are combining with domestic pressure to encourage governmental action against PVC (Healthy Building Network, 2005a).

In May 2003, anti-PVC forces got a tremendous boost when the vinyl industry dropped its lawsuit contesting New York State's refusal recognize vinyl as a "green material" and thus qualify for a state tax-credit. The state's new (2000) green building by-laws are the most progressive in the nation, and the PVC industry, through its front, the Resilient Flooring Association, put its substantial financial resources behind legal action intended to intimidate reform-minded governments. The industry was forced to backtrack before the growing public and state awareness of PVC impacts, and it withdrew its suit just days before an anticipated State Supreme Court ruling expected to go against the industry (Toloken, 2003).

The struggle against PVC continues, however, to be touchstone for the green building movement. As of early 2005, it is the single most contentious issue within the U.S. Green Building Council, which has apparently been under growing pressure from the vinyl industry (and manufacturing interests generally) as the USGBC's LEED building assessment system has become more popular and influential (L. Baker, 2004). Although many green building and community health activists have been shocked that LEED has not yet taken a definitive position against PVC (Healthy Building Network, 2005b), this situation in a sense testifies to the radical potential of green building assessment in industrial transformation.

As is true with other kinds of green materials, development of PVC alternatives depends on a combination of regulatory initiatives, economic instruments, and demand-creation for the alternatives. These measures can also speed up development and application of growing scientific knowledge about benign plant-based plastics and other alternatives. In Chapter VI, I will look more closely at community-based market initiatives that are concerned with creating regional markets for benign materials, and thus lowering the cost of production. It can be said here however that making *information about materials easily accessible* to builders, designers and retailers, is an important key to creating these markets, as well as increasing public awareness about more damaging materials, including PVC.

Strategic Issues in Building Materials Production IV:
Indoor Air Quality

In building, the most pervasive expression of the economy's toxicity is "sick building syndrome" and the related crisis of indoor air quality (IAQ). The problem manifests in the use phase of the building lifecycle, but is mainly rooted in production. A certain amount of pollution is attributable to combustion appliances, cigarette smoking, mould and mildew, radon gas, faulty ventilation and the like. But even this would be far less debilitating if it not for the toxic load of common building materials, furnishings and cleaning products. Thus while complete solutions do require measures in building operation, maintenance, ventilation, etc., this section will focus on the main sources of toxicity in building materials themselves. Most of these sources could be eliminated by good product design and selection.

Air pollution is nothing new to industrial capitalism, but its composition has changed substantially over the last century. Certain kinds of outdoor air pollution have been reduced in the developed countries, but the rise of petrochemical industry has introduced completely new kinds of substances to challenge the human immune system (Oliver & Shackleto, 1998). Indoor air pollution is not new, but it could previously be ignored as an insignificant externality. By the 1970s, the proliferation of new chemicals and materials, combined with the construction of more air-tight buildings, began to generate health costs that could be ignored no longer.

Air pollution is now typically two to five (and sometimes a thousand) times higher indoors than outdoors. In North America, over 60 million people suffer from asthma, allergies, respiratory disease, and various illnesses associated with indoor air pollution. Health symptoms are experienced by 20 to 30 percent of office workers. Besides serious respiratory and nervous system damage, millions experience more mild symptoms like headaches, nausea, dizziness, short-term memory loss, irritability, and itchy eyes and throats (Black & Bloech, 2002). The US Environmental Protection Agency (EPA) estimates that indoor pollution is responsible for more than 11,000 deaths each year from cancer, kidney failure, and respiratory collapse (Ligon, 2001). 50 percent of all schools have IAQ problems. 7.5 million Americans have asthma, and doctors have linked the doubling of asthma rates since 1980 to bad indoor air (Conlin & Carey, 2000). A new medical phenomenon—called "multiple chemical sensitivity" (MCS)—has devastated the lives of thousands of people whose overburdened immune systems react to even the smallest amounts of many different substances. Researchers have found that chemicalized air even leaves a film on office equipment that reduces its durability (H. Baker, 1997).

Cost-cutting externalities for some industries have become expensive burdens for others, with bad-air illness now estimated to cost US corporations over $60 billion annually. According to researchers at California's Lawrence Berkeley National Laboratory, US companies could not only save that $60 billion by preventing sick-building illnesses, but they could also could generate an additional $200 billion in worker productivity by creating offices with better indoor air. They found that the financial benefits of improving office climates can be 8 to 17 times larger than the costs of making those improvements (W. J. Fisk, 2000). Not making these improvements can have other penalties, since sick buildings have become serious legal liability problems for owners faced with suits from debilitated occupants and employees.

While the U.S. EPA has listed building sickness as one of the top five health threats to Americans today, existing occupational health and safety legislation offers little protection to office workers who commonly do not have the option of even opening windows for fresh air as they do at home. Legislated standards today are based on limitations of exposure to single chemicals in manufacturing plants. They have no way of dealing with the synergistic effect of the mixing of many kinds of volatile organic compounds (VOCs) in the chemical soup that constitutes the air of most contemporary homes and offices. Monitoring levels of toxic substances in buildings is difficult for the same reason. Buildings officially certified as “safe” often continue to cause major health problems for occupants (Conlin & Carey, 2000).

The offending substances that I am concerned with here (i.e. excluding mould, combustion gases, etc.) include VOCs like formaldehyde, toluene, naphthalene and limonene. A study carried out jointly by the State of Washington, the USEPA, and a consulting firm found over 400 different VOCs emitting from the 96 primary construction and furnishing materials. The most frequently emitting VOC, toluene, off-gassed from a third of tested materials. The offending materials include paints and stains; adhesives; caulks and sealants; carpets; resilient flooring; furniture; particleboard and composite wood; vinyl wallcoverings; ceiling tile; insulation; fireproofing; as well as cleaning systems.

The response to the IAQ crisis has been the rise of a virtual industry devoted to establishing and maintaining safe indoor environments. It includes engineers, health and building consultants, builders, architects, regulators, researchers, product designers, subcontractors and many more. Of particular note is a special class of building devoted to the "environmentally hypersensitive"—people who react to even minute amounts of manmade chemicals, and even many aromatic natural substances (like softwood resins). Special research, testing and consulting is necessary to provide homes which completely isolate them from threatening substances and hopefully allow their immune systems to strengthen. In Canada, Canada Mortgage and Housing (CMHC) has taken a leading role in commissioning research in this area and compiling directories of materials approved for the hypersensitive (Canada Mortgage and Housing Corporation (CMHC), 1997). The crown corporation has also moved strongly to encourage "healthy housing" for the general population (Canada Mortgage and Housing Corporation (CMHC), 2003), including sponsoring a housing design competition that resulted eventually in the building of Toronto's Healthy House, an "off-the-grid" advanced eco-house (Priesnitz, 1997; Rousseau & Wasley, 1997, p. 108-119).

Because my focus is the detoxification of building materials at source, I will not attempt to survey the whole of the healthy building movement, most of which is adaptive, rather than transformative. That is, it is concerned with helping people create healthy living conditions in a toxic world—not primarily how to detoxify production. Most of the literature on healthy building, for example, is pragmatically focused—and just as much concerned with siting, ventilation, mechanical systems, air sealing, construction practices and building operation as it is with product selection. Nevertheless these concerns with material selection can have a major impact on materials production, especially when there is some attempt to build markets for green products. While the concerns of CMHC, the US's HUD and EPA, for example, seem more adaptive, there are a number of other IAQ initiatives that are consciously intended to expand green production.

The LEED building assessment programme is one example. "Indoor environmental quality" is one its five assessment categories, amounting to 23 percent of its credits. (The other categories are "sustainable sites", 22 percent; "water efficiency", 8 percent; "energy and atmosphere", 27 percent; and "materials and resources", 20 percent). Because LEED is deliberately designed to rapidly expand green building practices in North America, it provides a lucrative market for products that meet LEED approval. This is also true for other building evaluation programmes—like the UK's BREEAM—and the various eco-labelling programmes like Canada's eco-logo, the US's Green Seal, and the EU's Flower.

Another example is the Greenguard Environmental Institute, based in Washington DC, which operates a certification and labeling program for interior products and building materials, and which touts itself as the only worldwide testing program for low-emitting products. It was launched in June 2000, as a Registry of low emitting indoor furnishings and building materials. It provides constantly updated information on newly certified products, like low-VOC paints and non-emitting office furniture, to architects, specification writings, procurement officers, etc. (Greenguard Environmental Institute, 2003). Greenguard offers another example of the role of information in driving green development. In Chapter VI, I will return to this relationship with a more explicit focus on consumer demand.

CHAPTER IV: RECYCLING
RECYCLING, REUSE AND DECONSTRUCTION

It is the realm of recycling that exposes the organizational irrationality of the industrial economy like no other. It juxtaposes possibilities for a closed-loop Lake Economy against the existing linear River Economy. But that is only if we can look beyond superficial forms of recycling patched into the accumulationist machine and see the full implications of closed-loop organization based in service.

For building materials, this involves a fundamental appreciation of what a building is and how it relates to change. A building is many things and serves many needs, but from a materials perspective, a building is basically a *holding device for materials*. As noted earlier, compared to most other products, buildings last a long time. We can, therefore, look at the holding patterns created by buildings in two key ways: their *durability* (how long these patterns and the materials within them last) and their *adaptability*—how easily and ecologically these patterns release old materials and incorporate new ones. These two characteristics roughly correspond to what some analysts (Bringezu, 2002) see as *dematerialization* (using fewer materials) and *rematerialization* (using them in more or less closed cycling loops).

The problem with existing forms of building within industrial capitalism is that they express precisely the wrong combination of permanence and change. On one hand, not only are buildings and materials are not as durable as they should be; but they are also often turned into waste well before their physical lifetimes are up. On the other hand, despite the apparently rapid, arbitrary and wasteful change carried out by the development industry, buildings are not all that easy to change. Critics like Stewart Brand (1994) have gone so far as to argue that the design and building professions are actually mobilized *against* change, making adaptation all the more difficult, wasteful and expensive.

What is true about buildings is equally true about materials: that is, they are also not designed for adaptation—that is, for recycling and reuse. Today there is some effort to recycle materials like old tires and plastic pop bottles into the production of carpeting, flooring, and upholstery. But despite many positive intentions, this may cause new environmental problems—for example, generating indoor pollution and aggravating chemical sensitivities because these materials were not designed with these uses in mind. In most cases, such examples of recycling are actually examples of "downcycling"—of employing the materials in a degraded form that will extend the materials lifecycle one brief round before they become a disposal problem (McDonough & Braungart, 2002).

It is certainly true that implementing more ecological relationships is an incremental process, and that many compromises must be made to make the best use of existing materials. In beginning, in order to "mine the waste stream", we will necessarily have to do the best we can with toxic or composite materials that were not intended for recycling. But it is also essential that we keep the ultimate goal in mind because the most fundamental solutions lay in product and building design. In all too many cases today, superficial forms of recycling are being used to reinforce, or divert attention from, larger anti-ecological patterns that should be altered. In this chapter, I want to look at some of the larger design goals, as well as transitional mechanisms and necessary compromises entailed in gradually closing the loops and tightening material cycles.

In the spirit of the *hierarchy of priorities for materials efficiency* summarized in Chapter I, a "ladder" of priorities in building for the circulation of materials includes:

> maintenance and conservation of buildings ⇨ renovation and reuse of buildings ⇨ reuse of building elements ⇨ material reuse ⇨ material recycling ⇨ material downcycling ⇨ material disposal.

Both the green building and recycling movements—through networks like the Healthy Building Network and the Grassroots Recycling Network—have persistently expanded their perspectives to prioritize more fundamental solutions to waste expressed in the notion of "zero-waste" (Seldman, 2003). This chapter will generally follow the ladder of priorities for a zero-waste strategy in the construction industry, beginning with the building level and moving toward the materials level.

Buildings: Time, Use and Change

When we think of buildings, we usually think of their spatial impact. As mentioned earlier, cheap fossil fuels have made possible an irrational and inefficient spatial fragmentation of the built environment. Such wasteful patterns have been aggravated by the more recent channelling of the information revolution into financialization and a speculative Casino Economy, which has extended global production-consumption loops while disguising real social and environmental costs (Milani, 2000).

For buildings, this use of space, however, is closely related to their relationship to *time* and change, and this is intimately connected to their use. As discussed earlier, an ecological economy must be geared to use, use-value, human need and qualitative wealth.

I have also described how, compared to most industrial products, the *use* phase of buildings and building materials is particularly crucial. They are long-lived and so their relationship to time is central. Can they be durable and/or gracefully re-absorbed into economic and ecosystem change? Buildings may be holding devices for materials, but like the human body or other dynamic ecosystems, the materials being held change over time; they change at different rates; and the holding patterns also evolve in response to need and context. Proper building design should consider all these things.

As Brand (1994) has demonstrated, however, the contemporary architectural profession has fetishized the external appearance of buildings at the expense of both building adaptability and user needs. Studies—which have been studiously *ignored* by architects and developers—show that buildings are rarely used for the purposes they were originally intended. To the degree that designers have been even partially concerned with new building use, they have reified the immediate needs of the prospective clients with little thought to changing needs and capacity for adaptation to unforeseen circumstances. Architectural design competitions are based exclusively on photographs taken before occupancy, and, according to a UK study, fewer than one in eight architects ever visit their buildings after occupancy. "Post-occupancy evaluation"—a fancy term meaning user feedback—is a new field that has emerged despite architects, and is still far from the central design tool it should be.

Only part of mainstream architecture's failings, however, can be attributed to architects. The external focus of the design professions is encouraged by the whole development industry and property relationships which inevitably pit exchange-value against use-value. The power of money and the juggernaut of economic growth often block healthy adaptation or else force change that is too rapid. It is beyond the scope of this thesis to fully deal with many of these questions of ownership and stewardship, but I must at least briefly itemize some of these factors, as they pertain to buildings, since they do have an influence on materials consumption:

- The power of money and interest devalues or "discounts" the future, in effect presuming that people today have the right to the use of all future resources. It makes "economic sense" to make money on land and resources now, even irreplaceable ones, so that interest can accumulate. This applies to materials and resources—like virgin forests; but it also applies to buildings—most dramatically in the case of historical buildings. Underlying money's perverse priorities, of course, is a pervasive undervaluing of both nature and community.
- In capitalism, "time is money," but perhaps even worse, money controls time. An example is the interest on construction loans to developers and builders that encourages haste, poor quality and a distorted emphasis on externals. This so-called "time value of money" obscures and destroys what urbanist Jane Jacobs called "use-value of time". Beside the obvious destruction of quality of life by the development industry, the quest for short-term profit usually makes no medium-term sense, even in narrow monetary terms. As Jacobs writes, in an intelligent economy "time makes the high building costs of one generation the bargains of a following generation". Speculation and short-term profit destroy these bargains. Jacobs and Brand point out that premature destruction of the past can limit the future—in that older buildings can actually be more freeing to users

than new ones, and that most economic innovation happens in old buildings (Brand, 1994, p. 84).

- Real estate markets, which tend to be volatile, can kill communities and buildings. Both boom and bust markets can be damaging. Bust markets obviously devalue and bankrupt communities. In boom markets, land values in urban downtowns overwhelm the value of existing buildings, which become disposable. They encourage high-rise development (to get the most rent per hectare), while property tax assessments penalize homeowners for making improvements. Similarly, in the suburbs, the treatment of homes as investments rather than habitat creates housing monocultures that are often enforced by rigid prohibitions on the kinds of renovation allowed.
- Absentee owner-renter relationships are usually deadly to a healthy built-environment. The owners have little stake in proper maintenance, and an economic incentive to minimize it, and the renters—who want to improve the building—have no equity stake in doing so.
- Mortgages once had something of a good side, in that they made outright ownership possible for many people. Their bad side, however, is that they represent a constant drain of resources, with two out of every three dollars spent on the purchase of a building going to pay interest. Christopher Alexander points out that these are resources that should rightly be devoted to continuing maintenance—which is absolutely critical to resource conservation (Brand, 1994, p. 86). What's more, mortgages have lost much of their good side and been submerged by a more sinister role in the modern debt-based Casino Economy.

Instead of facilitating home ownership, mortgages have instead become a means of hooking people on a debt treadmill, while becoming the main means of creating liquidity for debt-based capitalist economies. Mortgages now comprise more than 60 percent of the money stock in both the US and the UK. Correspondingly, statistics that show that fewer people in the US and UK now own their homes outright than in 1968 (Milani, 2000, p. 45; Rowbotham, 1998, p. 17).

- Mortgages also negatively influence building life. With mortgages usually set at 25 or 30 years, asset life is encouraged to match the finance period; and just when you own your home, you have to replace it.

These destructive impacts of the design profession and real estate markets spawned, beginning in the seventies, a reactive but also proactive grassroots movement that essentially constituted a revolution against the capitalist building industry's colonization of time. The ***movement for building preservation*** has been a distinct entity, quite different from either the green building and recycling movements, but in many ways equally important, operating on the top rung of materials efficiency ladder. The preservation movement expressed people's love for old buildings, and, as noted at the end of Chapter I, it may have been the only mass popular movement in the last hundred years with any major impact on architecture (Brand, 1994, p. 88). Dovetailing with growth of the preservation movement, the green building movement's growing concern with embodied energy (what ecologist Howard Odum called emergy) and life-cycle analysis has sparked a greater recognition of the importance of preservation, and the cultural dimensions of a healthy built environment. As the environmental movement has increasingly touted the importance of reduction and reuse over recycling, so also the green building movement has come to reaffirm A.N. Didron's (1839) famous maxim, "It is better to preserve than to repair, better to repair than to restore, better to restore than to reconstruct".

Building preservation is, of course, only one component in a strategy to conserve materials, and it does not directly deal with many of the unhealthy impacts of money and markets on building life listed above. Some initiatives to rectify some these imbalances will be discussed in Chapters VI (on consumption) and VII (on regulation). But it is important here to recognize that awareness is gradually growing within the green building movement of the importance of preserving, maintaining, and refining existing buildings as an essential dimension of resource conservation. For the newly emerging field of construction ecology this awareness is part of a more comprehensive understanding of how buildings change, and thus how buildings might be designed to facilitate positive change with minimal resource input. Theoretically, the most important breakthrough has been the concept of "shearing layers"—which I will consider before moving on to the recycling and reuse of individual materials.

Building Use and Adaptation: Shearing Layers

The notion of shearing layers was developed by architect Frank Duffy and adapted and popularized by Steward Brand in his ground-breaking 1994 book *How Buildings Learn*. It has implications for those concerned with buildings (through *adaptive design*), and those focused on materials (via *design for recycling*, and *design for* *deconstruction*). The layers—the six S's—distinguish between the ways different parts of a building age and change. The **Site** can be very long-lived, measured in geologic time; the **Structure**, anywhere from 3 to 300 (typically 50) years; the **Skin** or exterior envelope, around 20 years; the **Services**, typically from 7 to 15 years; the **Space Plan**, like interior partitions, would vary from 3 to 30 years; and the movement of furnishings and other **Stuff** might be daily or monthly.

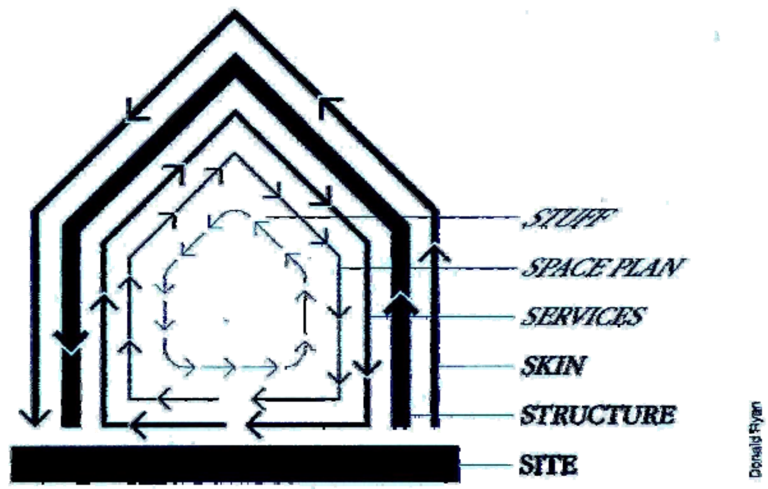


Figure 14. Shearing Layers: Different Rates of Change of Building Components
Source: Brand, 1994

Unfortunately contemporary designers do not acknowledge these layers in their designs and so create headaches and material waste for building users who are typically forced, for example, to tear up the structure of the building to make changes in the mechanical services like plumbing and electrical. In Brand's words (p.20),

> An adaptive building has to allow slippage between the differently-paced systems of Site, Structure, Skin, Services, Space Plan and Stuff. Otherwise the slow systems block the flow of the quick ones, and the quick ones tear up the slow ones with their constant change. Embedding the systems together may look efficient at first, but over time it is the opposite, and destructive as well.

The longevity of the entire building may, for example, hinge on how accommodating it is to new Services technology, especially in commercial buildings. The principle may even be applied to distinguish elements within the different levels which, depending on the building, may need more frequent maintenance or replacement: for example, elements of the building skin that are more exposed to weather, or components of the structure that are more likely to be changed to accommodate additions.

Good design takes into account how the slower and quicker changing elements in a building influence each other. The slow parts—site and structure—constrain and control the quick, as they express long-term trends. But especially in times of rapid change, the quicker (like electronic equipment) can influence the slower elements (like services or even structure).

An appreciation of shearing layers affects all kinds of decisions about building design, especially choice of materials. For example, in Brand's opinion slab-on-grade foundations, with services buried in the concrete and no basement storage space, are unwise. Because wood decays, wood structures are also not desirable—except for timber frame, since its wood is massive, usually exposed (therefore well-ventilated), and well separated from services. Wood is not desirable on roofs, but is a good choice for siding, since (compared to, say, vinyl) wood breathes, shows its wear in an obvious way, and is repairable piecemeal.

The notion of shearing layers has a social side as well. Truly adaptive building design not only puts the emphasis on building use and the needs of building users, but, because these needs are always somewhat unpredictable, the design has to allow users to shape the building to their needs. This is completely different from mainstream design geared to magazine photographs and quick-buck marketing. Despite the so-called organic architecture that he espoused, even Frank Lloyd Wright intended his buildings to be de facto museums with no capacity for user input. Mainstream design goes cheap in structure, and extravagant in finishes. Adaptive design goes substantial and durable in structure, and inexpensive in finish, allowing users optimal scope for providing their own. As Brand points out, the modernist maxim of “form follows function” was always a bit of a farce, since architects and developers were never truly interested in the needs of building users. By contrast, today’s green designers (Sim Van der Ryn & Pena, 2002) are making a case for “form follows flow” as the key principle of healthy ecological design—and so emphasizing the importance of adaptability.

Design for Recycling, Reuse and Disassembly

The concept of shearing layers has, as noted above, big implications for architects in both their design and material choices. But it has even greater implications for building system, component and product design—which can make the job of the green architect, builder or recycler much easier. The shearing layers concept also has implications for demolition and recycling at the end of the building service life—which I will examine in the next section—but the most fundamental solutions can only be implemented up front in the product- and system-design phase.

In this phase, some writers have distinguished between design-for-disassembly, which mainly refers to building elements or assemblies, and design-for-recycling, which involves separate materials (te Dorsthorst, Kowalczyk, Hendriks, & Kristinsson, 2000). Although Brand’s “Six S’s” is a convenient conceptualization, buildings, assemblies, and materials can be categorized in any number of complementary ways depending on the kind of building, its climate, its specific design, etc.

Crowther (2001) suggests it is helpful at times to break down buildings into a threefold *systems*, *product* and *material* conceptualization, examining a range of different concerns in each area. “End of life” scenarios can also be explored according to a four-fold framework of *building reuse* or relocation; *component reuse* or relocation in a new building; *material reuse* in the manufacture of new component; and *material recycling* into new materials. Figure 15 charts this kind of alternative to the existing linear throughput path.

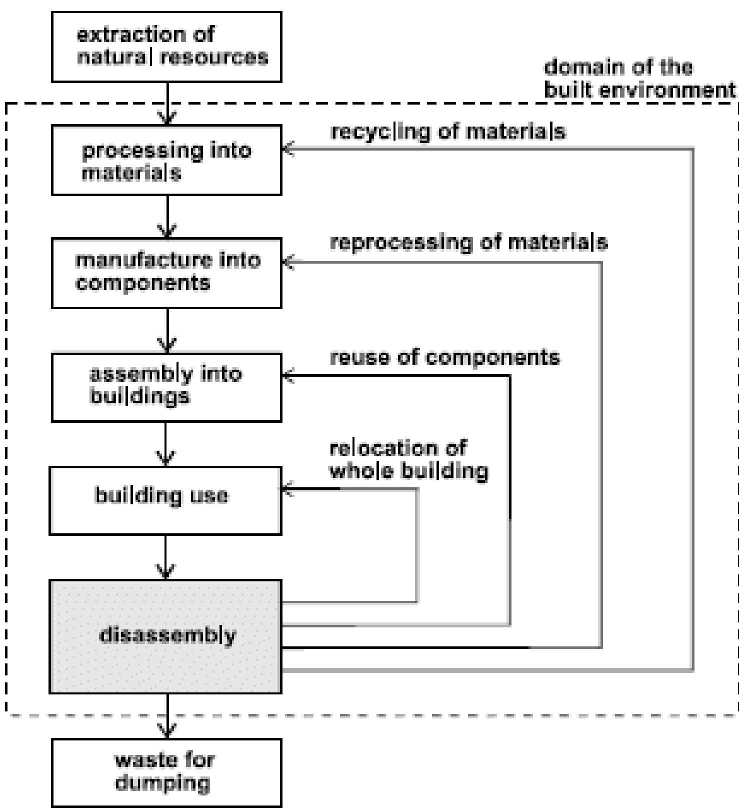


Figure 15. Possible End-of-Life Scenarios for the Built Environment
Source: Crowther, 2001

For materials, Bradley Guy (2002) emphasizes a threefold design strategy: *design for reuse*, *design for remanufacturing*, and *design for recycling*—with reuse requiring the least processing and recycling the most. The priority would be to minimize the need for reprocessing, and very generally, the aim would be to incorporate three basic principles (Berge, 2000, p. 11-15):

1. Separate layers, according to the understanding of shearing layers.
2. Possibilities for disassembly within each layer: sections that tend to wear quicker can be more reinforced or more easily replaced.
3. Use of standardized monomaterial components: including primary monomaterials like untreated wood and secondary monomaterials like concrete, glass or cellulose fibre. Components made of different materials laminated together aren't so appropriate since their various elements tend to decay at different rates, they are difficult or impossible to separate, and they make for inferior quality if recycled while blended.

Nevertheless, there are many dynamics to consider in proper design. Materials and components can be clustered in a number of ways. And much of the disassembly can and should take place away from the building site. The larger clusters should be dismantled on the building site, but many assemblies and specific materials can be separated offsite in places like factories and resource recovery parks. Guy and Shell (2002) highlight other questions relevant to how a building should be designed to be assembled and disassembled:

- What parts of the building support other parts? What parts of the building are self-supporting ?
- Where do specialized service inputs and outputs (telecommunications, electricity, water, gas, wastewater, supply and exhaust air) occur and how are these flow mechanisms constructed ?
- What parts of the building are subject to the most stresses from climate?
- What parts of the building are most subject to wear from human use and change from aesthetic preference?
- What parts of the building are most subject to alteration based upon functional, economic, life-expectancy, or technological requirements?
- What parts of the building are comprised of components and sub-components based upon a complex set of functional requirements and what parts serve only one function and hence are comprised of relatively homogenous materials?

- What parts of a building pose the greatest worker hazards in disassembly?
- What are the functional sizes of the principle elements and components of a building?
- What are the most expensive elements of a building, which have the highest reuse and recycling value and which impact the life-cycle efficiency of a building the most?

Sassi (2000) adds that reuse may not be appropriate for obsolete services, which would better be dismantled and recycled. As a rule of thumb, he says, recycling is most appropriate for shorter-lived elements, and reuse better for elements that have longer life potential than their actual use in a building.

Phillip Crowther (2001) lists 27 key considerations in design for disassembly:

1. Use recycled and recyclable materials
2. Minimize the number of types of materials
3. Avoid toxic and hazardous materials
4. Avoid composite materials and make inseparable products from the same material
5. Avoid secondary finishes to materials
6. Provide standard/permanent identification of material types
7. Minimize the number of different components
8. Use mechanical rather than chemical connections
9. Use open building system with interchangeable parts
10. Use modular design
11. Use assembly technologies compatible with standard building practice
12. Separate the structure from the cladding
13. Provide access to all building components
14. Design components sized to suit handling at all stages
15. Provide for handling components during assembly and disassembly
16. Provide adequate tolerance to allow for disassembly
17. Minimize numbers of fasteners and connectors
18. Minimize the types of connectors
19. Design joints and connectors to withstand repeated assembly and disassembly
20. Allow for parallel disassembly
21. Provide permanent identification for each component
22. Use a standard structural grid
23. Use prefabricated sub-assemblies
24. Use lightweight materials and components
25. Identify point of disassembly permanently
26. Provide spare parts and storage for them
27. Retain information on the building and its assembly process

Two of these guidelines deserve some elaboration. Number 6 insists on the importance of labeling all materials so that future users will always know what its constituents are, and therefore what its capabilities and limitations are. By the same token, all buildings should always have record books which detail how the buildings went together and all work done subsequent to original construction. Information is the lifeblood of ecological building and design. Number 8 specifies the use of "dry" or mechanical connectors (instead of adhesives, caulks, etc.) to facilitate disassembly. The challenge is doing this in a way that does not compromise building performance—like energy efficiency or protection from moisture damage.

Deconstruction

While design for disassembly is the goal of building design, the recycling of building materials today must meet the challenge of a built-environment that is not currently designed for recycling. The existing construction industry is preoccupied with "buildability" or assembly, but not with disassembly. It must be concerned with waste disposal, but rarely with "end of product life scenarios". The green movement must figure out how to increase recycling in this context, and green architects and builders must select from a limited and unsatisfactory palette of materials. Until materials are designed to be resources over their entire life cycles (thereby eliminating the concept of waste), green economic initiatives must learn to "mine the waste stream."

To this end, the realm of ***deconstruction services*** is one of the most exciting and rapidly growing areas of the green building movement. Deconstruction is just a new term to describe an old process—the selective dismantling or removal of materials from buildings before or instead of demolition. In fact, it was the norm in many places before the beginning of the 20th century. But with the full-blown triumph of the postwar Fordist Waste Economy, and the maturation of the industrial "river economy", the modern "construction and demolition" (C&D) waste management industry left its conservationist past behind.

Today's new deconstruction industry is recovering some of its ancient practices, but the challenges facing the contemporary movement are much greater due to the complexity of contemporary products and building systems; material toxicity; and logistical problems of finding—or even creating—markets for recyclables. Deconstruction workers are in a sense transitional labourers in an economy metamorphosing from the wasteful brute force of conventional demolition to the clean elegant world of designed disassembly. Today's workers have to struggle with composite materials that are not easily separated, as well as building layers not so intelligently melded together. They and their supervisors have to deal with timetables that do not allow sufficient time for deconstruction. And they have to deal with a unlevel playing field where their C&D waste competitors can externalize the real costs of demolition onto society and the environment.

That said, the number of success stories is growing. In places like Hartford CT., Portland OR, Minneapolis, Vancouver and San Francisco, deconstruction initiatives are proving they…

- can financially compete with or outperform demolition firms
- create skilled permanent jobs for less than $6000 in training per worker (less than half of the US Housing and Urban Development Department [HUD] typical training allowance)

- create opportunities for worker-owned firms
- inject substantial capital into local economies
- provide opportunities for secondary materials manufacturing
- save substantial public money in waste disposal

The appeal of deconstruction is spreading, exhibiting much of the enthusiasm of the recycling movement of the seventies. It is seen as a source of new skills, of environmental and building preservation, and of jobs and community economic development. According to Neil Seldman and Mark Jackson (2000, p.34) of the Institute for Local Self-Reliance (ILSR),

> If deconstruction were fully integrated into the U.S. demolition industry, which takes down about 200,000 buildings annually, the equivalent of 200,000 jobs would be created and $1 billion worth of building materials would be returned to the economy, with accompanying reductions in virgin material extraction.

The challenges to the new movement are great however. Besides the fact that neither buildings or components have been designed for disassembly,

- tools for deconstruction are lacking;
- disposal costs are still too low;
- markets for recycled materials are often scarce or depressed;
- retail networks of reused building material centres are undeveloped;
- many materials are hazardous or unhealthy;
- deconstruction takes additional time and new skill-sets;
- recertification of reused components is often impossible;
- building codes tend not to support reuse of building components;
- accessible public information about reused/recycled building materials is limited;
- general awareness of the benefits and opportunities is low.

The following table summarizes a number of opportunities and constraints of deconstruction:

Opportunities	Constraints
Management of hazardous materials	Increase worker safety/health hazard
Reduction in landfill debris	More time required
Economic activity via reused materials	Site/storage for recovered materials
Preservation of virgin resources	Lack of standards for certain recovered materials reuse
Removal of inefficient/obsolete structures	Lack of established supply-demand chains
Reduction in site nuisance compared to demolition	Buildings not designed for deconstruction and high variability in assembly techniques
Quality or aesthetic appeal of historic components of materials (ex., fireplace mantle, heart pine lumber)	Labour intensity in terms of skills and degree of materials processing, particularly removal of lead-based paint

Table 2. Opportunities and Constraints of Deconstruction
Source: Guy and Shell, 2002

The challenges listed above reflect the fact that deconstruction represents a fundamentally new paradigm of resource cycling. I have called this the “closed loop” or “lake” economy; but Robin Murray (1999), in his groundbreaking book *Creating Wealth From Waste*, calls this new paradigm “eco-modernization,” which is characterized by intensive recycling; more complex flows; decentralization; simple or specialist treatment; and innovation in collection, rather than high-tech plants. Murray sees eco-modernization as the alternative to what he calls the “chemico-energy mode of modernization”, which is much more centralized and capital-intensive; and whose main instrument is incineration. Murray (1999, p.98) points out that the ecological mode of recycling “demands the skills of a modern retailer, not a transporter of aggregates”—and that hauling aggregates is precisely the background of most of the dominant existing waste management firms (Laidlaw, Browning Ferris, Waste Management Inc., etc.). The “chemico-energy mode” is, thus, an attempt to deal with the problems of waste without altering the fundamental linear organization of the “River economy.”

Most of the problems facing the new deconstruction industry derive from the green paradigm's radically different treatment of resources, labour and knowledge. Taking buildings apart requires far more subtlety, ingenuity, knowledge and time than brute-force demolition. Workers require more training, and greater precautions are necessary to guarantee worker health and safety. Deconstruction contractors need to know more about materials, how to safely handle them, and how to gracefully get them to markets for reuse or recycling. Dealing with materials for reuse adds additional complexities to simple recycling—for storage, inventory, handling, transport and markets. Guy and Shell (2002) point out that deconstruction means that "demolition and building contractors become materials suppliers", with all the managerial complexity this involves.

Deconstruction companies exhibit the retailer-like flexibility that Murray argues is the hallmark of new forms of intensive recycling. Some firms employ sale-from-site marketing strategies for their salvage, where saleable items are inventoried and displayed for tours of potential buyers. Other firms are vertically integrated, making use of the salvaged materials in their own construction projects or salvage yards (Yost, 2000).

Many of the new deconstruction firms feel that they can be competitive with conventional demolition even on an unlevel playing field. Some companies are handling time pressures for site dismantling by "panelizing" deconstruction—cutting away large subsections of the building for detailed separation away from the job site (Yost, 2000). Other companies, like Portland's DeConstruction Services, simply assign more workers to the job in question. According to manager Jim Primdahl, "If the time line is a big issue to the contractor, then we will get in there with a big enough crew to get it done." At a local college, for example, his crew had ten days to deconstruct three of six houses and finished the project in nine days with about 25 workers (Block, 2001, p.43).

Primdahl's company also feels it can compete with demolition firms strictly on the basis of disposal costs. "What we have discovered is that our crews are cost competitive straight up with the bulldozers," says Primdahl. "Prior to the development of our program, it was an industry absolute that there is no way a deconstruction crew could take a house down cost competitively with a bulldozer. We have proven that simply not to be the case." Although 35 percent of the company's revenues come from recycling revenue, DeConstruction Services focuses the efforts of its workers on efficiency of deconstruction, period. "We never go onto a job site in exchange for the materials, which has allowed us to have one of the only economically self-sustaining deconstruction programs in the United States," says Primdahl. He argues "it frees up the crew in the field from picking up a board and thinking 'this has too many nails in it—if I take the time to pull the nails, what is it going to fetch at the yard?' The resale value of the materials is of no consequence to the crews whatsoever." (Block, 2001, p.44) The efficiency of deconstruction operations has also been greatly increased in only a few years time by new technology like de-nailing guns.

While Primdahl's company focuses on making deconstruction itself compete with demolition, there is no doubt that market situation for recyclables in the Portland area is crucial in the firm's success. About 85 percent of the material from deconstructed houses can be reused or recycled, primarily because recycling markets are relatively mature there (Block, 2001). Landfill tipping fees are also a factor, increasing the cost of traditional demolition. And Portland's building codes mandate that all building projects with costs exceeding $25,000 (including construction and demolition) must recycle materials generated onsite (U.S. Environmental Protection Agency, 2000).

The new firms are also imaginatively leveraging other incentives related to the growing market value of recycled materials. Many of the new firms—like Primdahl's Portland company and Minneapolis's Green Institute—are non-profits. This allows private owners who contract with them for deconstruction services to get tax deductions worth the value of recovered materials donated to the programme. The owner of one large house was charged $18,000 for the deconstruction and earned a tax deduction of about $53,000 for the value of the donated materials. A 1,200-square-foot house typically can claim from $5,000 to $8,000 (Seldman & Jackson, 2000).

The emergence of the Used Building Materials Association (UBMA), founded in 1996, has been a immense help in creating stronger markets especially for reused materials. The non-profit association has worked tirelessly to promote government, corporate and consumer purchase of reused materials; it has provided guidance for those wishing to set up new firms in the area; it has been involved in developing codes and standards for deconstruction; it has been encouraged technological development in the sector; and it has helped create building materials exchange information facilities (Used Building Materials Association (UBMA), 2003). As of late 2000, there were well over 200 used building material retailers in the US and Canada with the number growing rapidly (U.S. Environmental Protection Agency, 2000).

In Chapters VI and VII, I will return to the role of government in levelling the economic playing field and in creating new green markets, but here we must at least mention the crucial role of government in supporting deconstruction and recycling activity. In the U.S., demolition waste amounts to 92% of the total construction and demolition (C&D) waste stream of 136 million tonnes annually or about 125 million tonnes of demolition that is for the most part landfilled. C& D waste amounts to around a third of most municipal landfills. For municipalities, construction waste constitutes a huge cost and a huge potential for diversion to secondary materials industry (Kibert, 2002).

I mentioned above Portland's building codes that encourage recycling. Coordination and information, however, can often be as important as building codes and dump charges in creating new recycling industry. Seattle has a dynamic Construction Works programme with various incentives for local builders to recycle and reuse. Besides providing recognition to green companies, it provides technical assistance to builders about sustainable building practices, and training programmes for workers and managers. King County (Seattle area) also publishes a Construction Recycling Directory and Recycled Content Building Materials Product Guide, greatly increasing the ability of construction firms to source and cycle recycled products (King County Dept. of Natural Resources and Parks, 2004). Vancouver BC has developed a similar guide for salvaged materials, *Design Guide: Salvaged Building Materials in New Construction* (Mueller, 2002).

In areas where deconstruction firms have established themselves, they are having an impact on conventional C&D outfits. In many places, deconstruction and C&D firms are working together to efficiently take down buildings. The demolition industry focuses on the recycling of building materials, while the deconstruction firm's role is recovery and reuse. "Since we always work with a demolition company as a partner," states Pavitra

Crimmel of Beyond Waste, Inc., a Santa Rosa CA firm, "there is really full cooperation. We go in and get the reusable building materials. The demolition company takes down what we can't handle, recycling as much as it can and disposing of the residues" (Seldman & Jackson, 2000, p.34). The C&D companies have been pushed by the situation to recycle more and more of what they handle.

Recycling and Community Development

As suggested earlier, all places are not equal in the ease in which they initiate deconstruction activities. In particular, market conditions for both recycled materials, landfill charges, and development pressures in general, can affect the economic climate for the new ecopreneurs. HUD—the U.S. Dept. of Housing and Urban Development—has contracted for studies of conditions for what it calls “structural deconstruction” (that is, deconstruction that goes beyond the “soft stripping” of appliances, fixtures, flooring, etc.) and finds that there are particular conditions in some US cities that can facilitate deconstruction initiatives that constitute major economic development programmes (National Association of Home Builders (NAHB) Research Center, 2001b). They include:

- a large number of vacant, deteriorated properties that are constructed prior to 1950;
- a strong accessible reuse market including export markets and large metropolitan areas with a consistent demand for used building materials; and
- non-profit programs that are focused on achieving both social and environmental objectives.

It adds that military bases—where a good number of successful US deconstruction projects have already taken place—are ideal locations for deconstruction because of:

- control over project time constraints due to a lack of redevelopment pressure;
- consistent volume of similar building materials often installed prior to 1950; and
- reduced impact of local housing policies on existing structures.

(These possibilities for the military are no small matter in the United States, where the military occupies a substantial portion of the economy, with an impact on life in many communities.)

In locations where ideal conditions do not exist, HUD sees more proactive government involvement necessary to get the industry past take-off. It also sees great potential for deconstruction in involving greater numbers of inner city youth in the construction industry generally:

> Some inner city neighborhoods have incorporated deconstruction into renovation, remodeling, and demolition as a component of an overall revitalization strategy. The vertical integration of deconstruction into construction-related workforce development programs such as Step-Up, Fresh Start and YouthBuild can teach basic construction skills as a precursor to more advanced trade training and reduce the amount of waste going to local landfills (National Association of Home Builders (NAHB) Research Center, 2001b).

The HUD report adds that used building material retail outlets are proving to be a vital source of micro-enterprise in some inner cities and there is great potential for expansion. It emphasizes, however, that government support is essential.

Recycling—and reuse in particular—are the keys to both ecological and community development. As noted in Chapter III, the tightest (most ecological) materials loops demand proximity and thus have the great potential impact on local development. Deconstruction firms are simply the newest visible dimension of green community economic development. The growing used material retail outlets are another important piece of the puzzle, and we should expect to see conventional building supply retailers getting more and more involved with both deconstruction and used materials retailing.

New information technologies and the internet are making possible the growth of used materials exchanges. Because of the expense and inconvenience of storing and advertising used building materials, many tons of useful materials are currently disposed of in landfills or illegally dumped. The new exchanges make possible connections between sellers and potential consumers of used materials that would have been impractical in the past. The state of Washington has a sophisticated electronic exchange—2good2toss.com—involving 14 counties and municipalities. RecycleNet Corporation, based in Guelph Ontario, has set up a free used materials exchange, along with an exchange for construction and related equipment at <build.recycle.net>. Habitat for Humanity—well known for its efforts to provide affordable housing to low-income people—also maintains a network of Re-Stores in many cities around North America. Most of the emerging green building material directories (discussed in Chapter II) have special sections on reused or salvaged materials, and some, like Austin's *Sustainable Sources*, have internet exchanges.

Many of the new initiatives, like that of the Maine Housing and Building Materials Exchange (2004), have an explicit concern with providing low-cost materials for low-income people, and with providing jobs through a growing infrastructure of recycling and reuse. Philadelphia's Building Materials Exchange (BME) is a nonprofit clearinghouse for surplus and salvage building materials that also helps needy homeowners rehabilitate, improve, and maintain their homes. It makes local pickups free (Recycler's World, 2003). More than 120 Philadelphia not-for-profit groups working with people in need and/or people with disabilities have access to BME. It provides employment and training opportunities for adults who are on public assistance in Philadelphia (Mid-Atlantic Consortium of Recycling and Economic Development Officials (MACREDO), 2004).

One step beyond materials exchanges and retail stores are resource recovery parks (RR Parks). They have great potential to fully marry community development with major diversion of a region's waste stream. The phenomenon of RR parks is an innovation intended to displace dumps. California is a spawning ground in North America for these parks, because the state has mandated substantial diversion from landfills for every community. But cities like Toronto, suffering from an acute crisis of municipal landfill space, could benefit immensely from them. An RR park is a co-location of reuse, recycling and composting processing, manufacturing and retail businesses in a central facility to which the public can bring all their wastes and recoverable materials. They are sites for much more than C&D resources, but building materials have played a major role in their development. They are places where materials are brought for resale, or for reprocessing and resale. They are also places where businesses can share space, operating equipment like forklifts, repair services, management and technical expertise, accounting services, job training and much more. They would also feature showrooms for various products. They would be an ecological-economic nexus for public-private cooperation and all kinds of networking (Liss & et al, 2002).

Several are now in the process of development in California—in Cabazon, San Leandro and Berkeley. They have great potential to connect construction and manufacturing activity, particularly through interfacing with eco-industrial parks and networks (Lowe, 1997). The development of RR parks would go hand-in-hand with the creation of secondary materials industry, fully closing the loop of regional materials cycles. The generalization of such a commitment by local, provincial and state governments to this level of "mining the waste stream" would clearly be a revolutionary development. It would create conditions to facilitate a breakthrough on the "front end" of building and product design, to actively encourage design for disassembly and deconstruction—effecting in turn a further transformation of deconstruction work.

Challenges in Closing Material Cycles

The effort to create more ecological and efficient economies presents various dilemmas and paradoxes. On one hand, our existing River economy is so wasteful—and so laden with unnecessary social costs—that improvement is easy. Behind every cost of environmental improvement are several opportunities and paybacks, many of them "free". As Amory Lovins says of energy conservation, "it's more than a free lunch—it's a lunch you get paid to eat." (Stipp, 2002). On the other hand, waste and exploitation is structured into the industrial system, and the path to fundamental structural reform is not always clear, especially in the face of massive inertia and stubborn resistance by powerful vested interests. This is particularly true for those architects, builders, etc. who, to paraphrase McDonough and Braungart (2002), want to "do good, and not just less bad."

This is particularly obvious in the realm of materials selection. Green architects and engineers must at the moment select from a fairly limited palette of materials if they are to design ecologically. With the development of less toxic and energy-intensive materials, and the generalization of design-for-disassembly (on the product and building level), the palette will increase. But at the moment, designers must make hard choices for the environment and community development.

There are few simple answers—so much depends on context. Wood, brick, concrete, metal, even plastics: all have their proper places, but it is likely quite different than their current uses.

Wood: North America is using way too much wood, over 15 percent of global production by only 5 percent of the world's population (Edminster, 1997). It is being used for inappropriate applications (e.g. paper, roofing) and not recycled or reused. Yet, as Guy and Shell (2002) point out, wood is a highly preferable material in design for deconstruction since it is flexible for both reuse and recycling, a "natural" material, and can be readily connected using interstitial connecting devices such as bolts.

Wood is a key element in deconstruction efforts today. In fact, of all materials, wood has thus far been the main prize of deconstruction, especially in residential building. It is not uncommon for wood to comprise a third of recovered materials, and for wood recovery rates to achieve 90 percent. The average house in North America contains 13,000 board feet of lumber, most of which is ordinarily bulldozed and dumped (Holmes, 1997). The rise of new industrial subsectors that make comprehensive use of wood residuals (e.g. for engineered wood or composite decking lumber), combined with demand for high value wood in niche markets, has provided ready outlets for recovered wood (Seldman & Jackson, 2000).

As discussed, however, in Chapter II's section on engineered wood, even the use of wood waste in engineered wood products and wood-plastic decking lumber is an ambiguous development. Combining wood waste with polymers or toxic glues may only be delaying a disposal problem one brief life-cycle. Keeping wood separate, and reducing its use and encouraging its reuse may be a better way to cycle it. More attention needs to be given to how materials can be reused, recycled or even upcycled. What is called recycling today is more often than not downcycling, the use of a material in a more degraded state that won't likely allow further recycling.

One safe strategic priority is a greater emphasis on salvage—and therefore reuse. Webster (2002) points out that currently the salvage rate of wood members is roughly proportional to the member size. Timbers (6x and bigger) are frequently salvaged, while dimension lumber (4x and smaller) is rarely salvaged. This suggests designers need to be employing timber frame or post-and-beam construction more, and we need to be finding ways to reuse smaller framing members. Building codes must be revised and appropriate forms of grading must be developed to encourage wood reuse, particularly structural wood. Another strategic priority is the substitution of wood by other natural materials—cob construction, rammed earth, strawbales, etc.—that are both plentiful and can be easily recycled.

Concrete: As I discussed in Chapter II, concrete has its place, but only if (1) its inappropriate use can be reduced, (2) its Portland cement content reduced, and (3) it can be recycled and reused much better than it currently is. Today much concrete demolition goes to a form of recycling—in road beds for new highways. But this is largely downcycling, and in an ecological society, highway area should be considerably reduced. Design for disassembly is a necessity if concrete is to be properly reused, and improved recycling depends on better separation of concrete-masonry streams of undiluted concrete rubble, undiluted masonry rubble, mixed stony material, and mixed C&D waste (as discussed in Chapter II).

Brick: Brick can and should be reused more, but this depends on more appropriate use of brick, separation between different kinds of brick in deconstruction, and the use of mortar which is better suited to disassembly. Interior bricks (salmons) and exterior bricks (hard-burned) currently tend to get mixed up in demolition; they should be kept separate to be reused appropriately. The biggest cost of reusing brick is clean-up. The Portland cement that is currently used is too hard and strong for the reuse of brick—making clean-up difficult and costly (Webster, 2002). As with wood, lead paint contamination can be a problem for older brick.

Steel: Steel is also a material with great potential utility for design for deconstruction due to its ease of recycling through a thermal process and ability to span large distances with less mass of material than concrete for instance (Guy & Shell, 2002). But currently, while it is often recycled now (about 40 percent), it is rarely salvaged (Webster, 2002). Although an improvement over virgin steel-making, recycling is very energy-intensive; while the impacts of salvaged steel are mainly in its transport and refabrication—which are much less than recycling. One of the most interesting features of the Phillips Eco-Enterprise Center (PEEC) in Minneapolis was its incorporation of salvaged steel joists.

Plastics: There is clearly too much plastic in C&D waste, some of it contains heavy metals such as lead, and some of it (notably PVC) generates dioxin in production and disposal (see Chapter II). New kinds of bio-plastics can be helpful, but much plastic needs to be eliminated, and whatever is used needs to be more easily separated from other materials. Some waste plastics can be shredded and used as filler in other materials such as concrete, and plastic waste materials from households can also be recycled to obtain artificial lightweight aggregates for mortars (Elias-Ozkan & Duzgunes, 2000).

This brief discussion only touches on a small portion of considerations related to building materials. As suggested at the beginning of this chapter, there are also many economic and general infrastructural considerations that currently militate against both recycling and reuse. And cultural factors are also involved. Sassi (2000), for example, points out that UK studies show that many materials are junked well before their service life is exhausted, with only 25 percent of materials replaced because of maintenance. That is, most renovation is done for reasons of style or function that has nothing to do with materials wearing out.

Nevertheless, even before new forms of liability (like extended producer responsibility) and design for disassembly are implemented, the potential for recycling and reuse is great. The following table summarizes a 1997 study by the US National Assn. of Homebuilders which gives some sense of the technical potential in residential building for deconstruction and recycling in current conditions . Note that the numbers do not include a full, poured-concrete basement.

MATERIALS RECOVERED		Quantity	Volume cu. yds. (cu. m.)	Weight tons (tonnes)
Reuse (resale)	Framing lumber /sheathing (higher quality)	3420 bd. ft.	22 (17)	3.5 (3.6)
	Framing lumber /sheathing (lower quality)	4377 bd. ft.	27 (21)	4.5 (4.6)
	Brick	5500	12 (9.2)	17.9 (18.1)
	Hardwood flooring	950 sq. ft. (90 sq. m)	7 (5.4)	1.1 (1.2)
	Stair units / treads	20oak treads	4 (3.1)	0.4 (0.4)
	Windows (aluminum double-glazed replacement)	24	2 (1.5)	0.3 (0.3)
Reuse (donation)	Tubs / toilets / sinks	4 (each)	3 (2.3)	0.7 (0.7)
	Doors	24	3 (2.3)	0.4 (0.4)
	Shelving	--	0.5 (0.4)	0.1 (0.1)
	Kitchen cabinets	16	1 (0.8)	0.2 (0.2)
Recycle	Rubble (unsalvageable brick)	--	88 (67.3)	61.6 (62.6)
	Metals	--	13 (9.9)	2.3 (2.3)
	Asphalt shingles	--	10 (7.6)	3.5 (3.6)
DIVERSION SUBTOTAL			192.5 (147)	92.5 (98)
MATERIALS LANDFILLED				
	Plaster	--	48 (36.7)	21.6 (21.9)
	Painted wood	--	26 (19.9)	4.2 (4.3)
	Rubble	--	7 (5.4)	4.9 (5.0)
LANDFILL SUBTOTAL			81 (62)	30.7 (31)
DIVERSION RATE			70%	76%

Table 5. Material Breakdown for a Two-story, 2000 sq. ft. Wood-Framed Multi-Family House with Brick Exterior
Source: NAHB Research Center, 1997

It is essential that alternatives in the realm of recycling and reuse be implemented in the existing economy. The growing green building movement—expressed in green building assessment systems going mainstream via LEED, etc.—should continue to create pressure on both markets and government for infrastructural support. In Chapter VII, I will return to regulatory changes—like extended producer responsibility (EPR)—which are essential to generalize these relationships. But to some degree, grassroots alternatives are necessary first to offer models and examples for social action.

I have argued that closing the loops of production and consumption involves greater localization and regionalization. Now it's time to look at a realm that provides the most radical examples of the “disintermediation” of a green economy (the elimination of middlemen and unnecessary processing) and the integration of construction within natural process—that of natural building.

CHAPTER V: ALTERNATIVE MATERIALS
NATURAL BUILDING

> "What we have done in the last 60 years is to trade knowledge of local materials for easily replicated, dumbed-down knowledge of standardized manufactured goods." —Ted Butchart

The other chapters of this thesis are about, successively, the evaluation, production, consumption, recycling and regulation of building materials. This chapter is, in a sense, about *all* of those dimensions in one chapter because it is about the ultimate alternative, natural building materials. By "natural" I include the materials used by the many varieties of pre-industrial and vernacular building—stone, earth, straw, timber, grass, etc. These tend to be derived more directly from the earth, and also more safely and naturally assimilated by the earth at the end of their service lives. But the contemporary natural building movement also encompasses some unusual new building methods that also make the most of plentiful local materials, even if those materials (waste paper, old tires, etc.) are very industrial in origin. Perhaps most interesting is how the movement is combining elements of old and new, manufactured and self-made. It is doing this by combining materials (e.g. straw bale with cob; timber with cordwood-masonry; rammed earth with tire walls), and by the observation and application of thrifty traditional building principles to new materials, methods and situations. Some of the alternative building methods discussed in this chapter include rammed earth, straw bale, cob, light-clay, adobe, compressed earth block, cordwood masonry, timber, earthship, earthbag, bamboo, and stone.

What all these methods have in common is that they attempt to radically short-circuit the extended processing of mainstream industrial materials. In doing so, they present a major challenge to industrialism's consumer values, its view of work, and its concepts of professionalism, bureaucracy and specialization. Natural building also presents a de facto challenge to industrial markets, since much of its labour, materials and energy is deployed completely outside the formal (or cash) economy. It constitutes what Toffler (1980) first called "prosumption"—the home-based production that mainstream economics would normally consider simply passive consumption. In this sense, the natural building movement is a logical progression from the owner-builder movement of the seventies, where it was mainly labour which was off the market. The materials of natural building are, almost by definition, indigenous—to the region and sometimes even to the building site. For this reason, the natural building movement is much closer to the appropriate technology, traditional and informal building movements of the underdeveloped world. Even without full costs built into market prices, the industrial system produces expensive building materials, which the Third World has neither the resources to support nor the income to afford.

While obviously concerned with resource efficiency, the natural building movement—more any other segment of the green building movement—is also concerned with community, with creative expression, intrinsic work satisfaction, and with establishing a new spiritual relationship to the built-environment and the Earth. Nowhere else in the literature on building materials is there such treatment of social justice, voluntary simplicity, mind-body awareness, vernacular design, and co-operative development. The natural building movement is, for this reason, both the counter-cultural soul of green building and a significant part of its technological cutting-edge. It may represent a comparatively small portion of green building today, but its direct and imaginative approaches make it central to the evolution of building.

As I will show, most of these techniques—old or new—are not purist in attempting to avoid industrial components or machinery. There is a healthy respect for many elements of mass production, modern science and various kinds of construction tools. But there is also a great respect for craft and for many traditional building methods and materials that were violently pushed aside by the industrial revolution. The industrial revolution coincided not only with a more specialized division of labour, but with an massive centralization and concentration of energy—much of which was considered as "free" and not tabulated by the accountant's ledger. The extraction, processing and refining of industrial materials is energy-intensive, making the "embodied energy" and "ecological rucksack" of commercial building materials relatively high. Natural building is an expression of the maturation of the green building movement, from its initial preoccupation with a building's operating energy-efficiency to newer concerns with *embodied energy*. The concept of embodied energy is, in fact, probably the core technical concern of natural building. But natural building's concerns—more than any area of green building—go well beyond the technical to the social and spiritual.

Building with (the) Earth

As Ted Butchard (2002, p.16) points out, the use of local and natural materials in mainstream North American construction over the last century was abandoned "…not because [these materials] are inferior in any way but due to historical forces that worked to reduce manual labor." The goal was not necessarily to reduce labour drudgery but to reduce labour costs and boost profits. This strategy of replacing labour with resources can not work in most of the world where labour is more obviously abundant and resources scarce.

Those who consider natural building a "marginal" or "fringe" activity should contemplate that less than a third of the world's population lives in buildings comprised of energy-intensive manufactured materials (Eisenberg, 2002). Between a third and half of the world's people live in some kind of earthen structure (Kennedy, 2002b). In many areas of the world, earthen construction is stigmatized as backward or lower-class, despite the fact that earth can be among the most durable, economic and beautiful of building materials. Most of its techniques are readily amenable to participatory construction and design, and so complementary to the spread of democracy in planning, economics and technology. The continuing and expanded use of earth-building is a given for underdeveloped countries, but both global sustainability and equality depend upon greater portions of the "first world" rejoining the planet in a greater use of earth and other natural materials. Earth or clay is used to make bricks or block, to pour into forms, to stack up for walls, to use as infill for wood and bamboo frames, to create floors, etc. Among the most prominent realms of earthen building are pise or rammed earth; adobe; light-clay; cob; compressed earth blocks (CEB); and many other composite materials combining earth and other (usually fibrous) materials. What follows is a concise survey of these materials.

Rammed Earth

Rammed earth is earth or mud mixed with clay or cement and packed into temporary forms. It is one of humanity's oldest building techniques, especially after the emergence of settled communities. Jericho, the earliest known city, was built of packed earth and mud brick. The Great Wall of China, dating back over 5000 years, was made of stone and rammed earth. Rammed earth was used not only for simple housing, but for sophisticated structures—vast monuments, institutional buildings, temples and mosques (Easton, 1996).

Although most associated with arid regions of the world, rammed earth is also found in temperate climates. It was, for example, spread by the Romans and Phoenicians in their conquests. In the Rhone River Valley of France, it became the dominant form of architecture for perhaps 2000 years. Now called *pise de terre* by the French, these "packed earth" structures constitute about 15 percent of rural buildings there. In the Americas, Pueblo peoples utilized ancient earth-building systems incorporating mud and dressed stone in what is now the Southwest US. When the Spanish came to the area, they introduced adobe—sun-dried mud brick. On the east coast, the Spanish utilized a form of rammed earth (mixed with seashells) called *taipa* in building some of the first permanent structures in North America. In the US's oldest city, St. Augustine, we still find many examples surviving; while in South America, *taipa* has persisted for centuries as a dominant style, particularly in Brazil, Chile and Peru. French and German immigrants of the late 1700s and early 1800s brought pise to more temperate North America, where there are still a number of stately pise homes surviving in New York, Pennsylvania and New Jersey (Grometer, 2002).

In Australia, pise building was planted by European gold hunters in the 1850s, and became common in the dry timberless regions of Australia. Today Australia is experiencing a renaissance of rammed earth building, putting it on the cutting edge of this technology. Its success seems to be due not only to rammed earth's fit with the "rugged" and earthy self-image of Australians, but because in Australia framing lumber is rare and expensive, and rammed earth is not a radical change from the dominant form of brick masonry construction (Easton, 1996).

Figure 16. California Rammed Earth House
Source: Rammed Earth Works

North America has experienced three waves of rammed earth building since industrialization. The first two—in the 1840s and 1930s—were a response to economic hardship, expressing a quest for low-cost owner-involved housing. And both surges were eventually overwhelmed by the availability of mass-produced manufactured materials. The final wave of rammed earth building began in the seventies, spurred by the energy crisis and the birth of the modern green building movement, and is continuing today as part of a growing movement for natural building. Today the greatest activity in rammed earth building worldwide is concentrated in Australia, France, Arizona, New Mexico and California.

Compared to other earthen materials like adobe, rammed earth has greater crush strength and is much more resistant to erosion. As Daniel Chiras (2000) points out, the rocklike character of the cured rammed earth wall basically results from its replicating the process of sedimentary rock formation, but in a much shorter time span. Its thick variously coloured walls are attractive and can be built in a variety of regional and architectural styles. Any number of roof systems can be employed with them. Rammed earth is amenable to energy-efficient design, and provides lots of thermal mass, which is desirable for passive solar design. Unlike wood buildings, rammed earth buildings are termite and pest resistant, and defy earthquakes, tornadoes and hurricanes. They resist decay and are extremely durable. Fire actually hardens and strengthens rammed earth walls; and they are virtually soundproof.

A drawback of rammed earth, compared with other natural building systems, is that it can be exacting and cumbersome, and is probably best carried on by professional contractors. A crucial factor is the right soil mix, strong on mineral matter, with an absolute minimum of organic material. The ideal mix consists of about 70 percent sand and aggregate, and 30 percent clay which acts as the binder. The clay, however, has to be just the right kind—which is non-expansive; and in cold or wet climates, a certain amount of Portland cement is required to increase strength and water-resistance. While rammed earth makes good use of local materials, just any soil is not acceptable. Prospective soils must first be tested, and if necessary augmented by, e.g., road base or quarry fines from a local quarry. Mixing the material is also a challenge, making sure the clay is thoroughly crushed and integrated.

Building the forms and the tamping of the material in the forms is also a relatively unforgiving process. There are a number of forming systems available but most are best carried out by experienced builders. Rammed earth walls defy alteration, and require special provision for mechanical conduits, etc. Going beyond one story is certainly possible, but, with the current state of technology, increasingly expensive as the building goes higher. Rammed earth installation also requires lots of wood for forms, and obviously this is only an ecological proposition if the forms can be constantly reused. In cold climates, like most of Canada, rammed earth's great mass is also not enough to make it energy-efficient; it requires more insulation (typically external rigid insulation board, covered with stucco).

Because rammed earth is not the ideal do-it-yourself building method, it tends to be trapped between economic models. On one hand, like other natural building forms, rammed earth is an unfamiliar building mode to most contractors and officials. Most builders cannot so easily get into it because the technology specifically developed for it is minimal, and the building process is still way more time-intensive than mainstream building. On the other hand, unlike other forms of natural building, do-it-yourselfers can not simply decide to compensate for this lack of professional support with their own sweat equity—that is, without a lot of additional trouble.

One hopeful development in making rammed earth more attractive to the average contractor is a new technique developed by long-time RE builder David Easton. Called P.I.S.E. (for "Pneumatically Impacted Stabilized Earth"), the technique was inspired by the “shotcrete” or “gunnite” concrete installation technology of swimming pool builders. It requires only one form wall (with reinforcing steel attached), onto which the mixed earthen material is shot to the desired thickness, and then finished on the outside with a hand float. P.I.S.E. considerably reduces time and labour inputs, and utilizes the services of conventional building trades, thus enhancing its appeal to the mainstream building industry (Grometer, 2002).

The cost of rammed earth construction today is, in North America, roughly equal to wood-framed construction. But that cost should be considerably reduced if its popularity can be increased. New more user-friendly technologies—for both the professional and the do-it-yourselfer—are inevitable, and growing economies of scale promise new efficiencies in soil assessment, mixing and installation methods. On the spectrum of natural building, spanning from household/informal to professional/formal modes, rammed earth seems destined to carve out a niche in eco-building more on the professional and market side.

Adobe and Compressed Earth Blocks

Adobe is mud brick construction. Like rammed earth, it is one of humanity’s most ancient construction materials, with adobe bricks being perhaps the oldest manufactured building material. The term adobe is often credited to the Spanish, who are most responsible for spreading the technology globally via its imperialist adventures, but the word probably derives ultimately from the Arabic “attubah,” meaning “brick.” Evidence of mud brick construction has been traced back to Iraq around 6000 B.C. and Egypt circa 5000 B.C. The Moors carried it eventually to Spain, from where it was launched into the Americas around 1600 A.D. Despite this powerful trajectory, mud brick construction did predate the Spanish in the desert Southwest of North America, and one finds evidence of adobe construction in many areas of the world, including China. It has been a logical outgrowth of local resource potentials (Chiras, 2000).

Adobe is still a popular building method worldwide, but in North America it has suffered a similar fate as other natural building methods. In the American Southwest, the mass-production of building materials, coupled with cheap fossil fuel-based transportation, has turned adobe into a contradictory form—simultaneously looked down upon as poor people's housing, and promoted as a retro niche of luxury homes for the rich (McHenry, 2002). The ultimate in alienation is "fake adobe"—conventional wood-framed buildings featuring mock vigas and stuccoed to look like adobe.

Notwithstanding this fate, adobe is experiencing a renaissance in tandem with other natural building systems. New Mexico and Arizona are natural centres for this revival. But adobe enthusiasts are also demonstrating the applicability of adobe, like rammed earth, to non-arid climates. In New York, for example, researchers have documented over 40 adobe brick buildings around the state. Adobe homes are also found in Massachusetts, Nebraska, China and Japan. Besides needing additional insulation, the main challenge for adobe building in colder wetter climates is securing long stretches of warm and dry conditions for making and curing the bricks (McHenry, 1996).

Adobe bricks come in various sizes, depending on tradition and preference. In the US, for example, the common size is 10x14x4 inches (250x350x100mm), while in Iran they are 8x10x2 (200x250x50mm). They are stacked up with a mud mortar made from the same soil sources as the soil in the bricks. Many of the concerns of rammed earth apply to adobe. The proper mix is important: with about 20-30 percent clay. Having the right—non-expansive—clay is also crucial, as well as eliminating organic material (e.g. topsoil) from the earth mix. In addition, precautions must be taken in seismically active areas, usually adding vertical and horizontal reinforcing steel as the wall rises. Compared to rammed earth, adobe construction is much more conducive to self-build initiatives. The bricks can be made on site either by hand or by machine. In many areas they are also commercially available. Making the bricks requires minimal skill, and laying them is fairly easy, requiring few tools. Adobe bricks are also inexpensive, costing, for example, typically between $2000 and $3000 US-funds for a 2000 square foot home (Southwick, 1994).

Figure 17. Texas Adobe Under Construction
Source: Adobe Builder.com

Adobe bricks can be manufactured locally almost anywhere, although special care in drying must be taken in cold or wet climates. They rank as among the most environmentally benign building materials, with embodied energy a fraction of a wood frame or brick building. Adobe bricks can be recycled fairly easily, and, while they require thermal insulation in cold climates, they are conducive to solar design, and are great sound insulators (Romero & Larkin, 1994).

A variation on adobe—called Compressed Earth Blocks (CEB)—employs pressing machines that can create large numbers of bricks (blocks). The machines can be simple hand-operated affairs, or more complicated mechanisms with cams, toggles and motorized hydraulics. The simpler machines have had more widespread application since they are less expensive, less dependent on external fuel and more suitable for impoverished rural applications. Workers employing hand presses can make up to 500 blocks a day, and all the bricks necessary for a modest house in a week. Hydraulic machines can make all the blocks for a large house in a day. CEB construction has been employed around the world, from Latin America to Africa to India and the Middle East. CEBs are stronger in compression that regular adobe blocks (Nelson, 2002).

In composition, the main difference between adobe and CEB is the moisture content. CEB mixes are much drier than adobe. The block machine compresses the volume of the block by about 30 percent, aligning the moist clay particles, removing the air pockets and sticking the clay to the sand. Too much water would result in too much air space between particles when the block dries, weakening it. Over time CEB technology has experienced some interesting innovations—as, for example, shape changes in the blocks to accommodate reinforcement or to facilitate interlocking mortarless stacking (Chiras, 2000; Nelson, 2002).

Adobe and CEB are versatile examples of earthen construction that have great future potential—for development in both the formal and informal economies.

Cob

Cob is the English term for mud building, which is also sometimes called monolithic adobe. The term "cob" is an Old English root meaning a lump, loaf or rounded mass. The cob mix is made by combining soil, sand, straw and water; and walls are raised by piling up one handful or shovelful of the mix at a time. It uses no forms or bricks. Similar kinds of building have been common throughout the world. In England, cob houses were being built by the 13th century. Between the 15th century and industrial revolution, they became the norm in many places, particularly southwestern England and Wales where the subsoil was a sandy clay. English cob usually consisted of clay subsoil mixed with straw, water and sometimes crushed shale or flint. It was mixed either by people shovelling and stomping, or by heavy animals like Oxen trampling it (Smith, 2002a).

While many cob cottages were built by poor farmers and labourers working cooperatively, many townhouses and manors were also built of cob before the ascendance of brick construction. It was common for cob houses to go a century without needing repair, and tens of thousands of old cob buildings survive in England today (Smith, 2002).

After the virtual disappearance of new cob construction between World War II and the 1980s, a cob building revival took hold in the early 1990s, fuelled by historical interest and the real estate value of historic cob homes. It has used mainly the same methods as its historic ancestors. In the old days, a stiff mud mixture was shovelled with a cob fork onto the wall and trodden into place by workers on the wall. In a single day, a "lift" would average 18 inches (450 mm) high. It would be left to dry for as long as two weeks before adding the next lift. As they dried, the walls would be trimmed back with a paring iron, to between 20 and 36 inches (500 and 900 mm) in thickness, leaving them plumb and straight. Today cob builders make their walls about 2 feet (600 mm) thick at the base; they can use a tractor rather than oxen for mixing; and they often add a fine gravel of crushed shale to reduce shrinkage and cracking. A number of different techniques are being used to build the walls, most a variation on either the mud "loaves" or the shovelling method.

Figure 18. B.C. Cob House
Source: Cobworks

Cob can create structural bearing walls, even for two stories, or it can be used in combination with a post-and-beam framework. In rainier climates, a post-and-beam method allows the roof to be built before the walls, creating a protected work space. The walls can be finished with a breathable plaster (cement plaster is out since it doesn't breathe) to both protect the exterior and reduce dust inside. And cob is an eminently artistic medium, able to be shaped in any number of ways, typically expressed in "organic" styles. The mouldability of cob also facilitates built-in seats and shelving within the building (Chiras, 2000).

Cob can be used in a wide variety of climates, but like other forms of earthen construction, it must be insulated in cold climates. Environmentally, it is an excellent material, with a very low embodied energy quotient. Its raw materials are available almost everywhere, and they are literally dirt-cheap. It is also an ideal building process for owner-builders and do-it-yourselfers. It is very labour-intensive, and while amenable to high levels of craft, quality cob construction demands only very simple skill-sets (Berlant, 1999). Even children can participate in cob-building. It doesn't require either the forms and hardware of rammed earth, nor is the soil mix as critical and unforgiving as either adobe or rammed earth. Cob is very durable, fireproof and relatively adaptable. It appears to be a building technology with vast potential for both community development and environmental regeneration.

Light-Clay

Light-clay is a hybrid form of construction that draws on some of the oldest and newest thinking in building. It combines clay with fibrous materials like straw, hemp, wood chips, etc., usually as infill for a wood frame structure. It is related to some of the oldest vernacular traditions like "wattle and daub", where an infill mixture of clay and straw (daub) was plastered over interwoven willow whips (wattle), like plaster on lath, between some kind of wood framework. When dry, the daub was plastered with a mix of lime, sand and animal hair, and then painted. A more direct antecedent was the tradition of German builders, dating back around 400 years, of filling the walls of wood structures with a mixture of loose straw coated with clay (Chiras, 2000).

Modern forms of light-clay building were pioneered in Germany beginning in the twenties, but, as with most other natural building systems, did not take off as a major movement until the 1980s. Most current methods involve the shovelling of the mixture into low temporary forms which are comprised simply of two 2-foot-wide sheets of plywood tacked onto both interior and exterior sides of structural posts. The mixture is tamped, before a next lift of plywood is tacked on, and the process repeated. Plywood from the first level is moved up to the third, then the second to the fourth, and so on. If desired, horizontal or vertical reinforcement can be used—for example, saplings or small dimension lumber at 16 in. (400 mm) on centre. A number of other forming systems can be used with light-clay, using reed mats and other devices, as builders and researchers are constantly innovating new systems. It is also possible to make bricks, blocks or panels with clay and fibre which can then be used in a pre-dried state (Andresen, 2002). Some producers are hoping to eventually automate production and mass market these natural products.

One of the great benefits of light-clay is that it can provide much greater insulating values than other forms of earth construction. In fact, the composition of the clay-straw mixture can be varied in a single building depending on preferences for the wall. North walls, for example, can be designed with a larger straw content for greater insulation values, while south-facing walls can be designed with more clay for greater thermal mass characteristics.

Throughout the 90s, there was also experimentation with the use of wood chips instead of straw. Builders found that the drying time, shrinkage behaviour and labour-intensity was reduced when using wood chips. The chips could be dry or green, and could range from sawdust to chunks up to 2 in. (50 mm) in diameter.

Like most of the other forms of earth building, light-clay is very environmentally benign. It is low-embodied energy, completely recyclable/compostable, and is insulating. It is super low-cost and requires few special skills. If it has any major drawback, it is the long drying time—approximately 12 weeks for a 12-inch (300 mm) wall during the warm season.

Light clay is a building form that seems to have unlimited potential, especially in temperate to cold climates where insulation is necessary. Innovators are working on different methods, tools and products that have applications for self-help building and for commercial-professional construction (Gaia Architects, 2003).

Straw Bale

Straw bale construction is one of the youngest, but probably the most well-known form of natural building, at least in North America. It has great potential not simply because it uses an abundant benign material, straw, but because of its high insulating values which equal or exceed those of “super-insulated” wood frame buildings.

Straw is a material found where grains are grown. It is not hay, but the more inert shaft of rice, wheat, rye and other grains. When baled it has tremendous strength, able to support six times more weight than a standard 2x4 wall (Chiras, 2000).

Straw bale's ancestor systems include Asian and European practices of building with tied bundles of straw stacked in mud mortar. But straw bale building really begins in the 1880s with the invention of the mechanical baler. Experimentation soon began in northwestern Nebraska, where people tried both baled grass and straw. Intended originally as secondary or temporary structures, these buildings were soon found to be more comfortable and economical than most conventional building forms. Cheap transportation and imported manufactured building products, however, soon destroyed the nascent straw bale industry (Steen et al., 1994).

The straw bale revival began in the late seventies and early eighties, taking its place at the head of the natural building pantheon in the nineties. Innovators saw in it a super-benign form of building with great potential for self-help and owner-builder construction. Today we find straw bale buildings in almost every state and province in North America, and rapid growth all over the world. The largest concentration of straw bale structures is in Arizona, New Mexico and California; but they can be found in Canada, Mexico, Russia, Germany, Sweden, China, and Australia, to name only a few places.

Straw is basically a waste product of grain production, and every year vast quantities are burned after harvest, generating substantial carbon dioxide emissions that contribute to global warming. Making good use of waste straw not only avoids this destructive combustion, but it reduces the use of lumber and synthetic building products. And by creating super-insulated buildings, straw bale construction further reduces carbon emissions otherwise generated by heating and cooling. Researchers have discovered that each straw bale house built in China and Mongolia will over a 30-year period reduce carbon entering the atmosphere by 136 metric tons. China has the capacity to house 1 billion people in straw bale houses (Wanek, 2002).

Straw bale building is labour-intensive but a fairly simple method, amenable to owner-build and do-it-yourself initiatives, although the number of professional straw bale contractors is growing rapidly. Bales can come in different sizes: a common two-string bale might be 18 in. wide, 14 in. high, and 35 to 40 in. long, and weigh 50 pounds. A three-string bale might be 24 in. wide, 14-17 in. high and 32 to 47 in. long, and weigh 75 to 100 pounds. Bales are usually stacked without any mortar right on top of each other and pinned with metal rods or bamboo sticks. They are finished with either cement stucco or earthen plaster, inside and out (Steen et al., 1994).

Figure 19. New Mexico Aboriginal Workshop in Infill Strawbale
Source: Strawbale Group / Builders Without Borders

Straw bale walls can be either structural or in-fill. As structural walls they are usually for single-story or 1 ½ story buildings. The roof rests on a wooden beam that crowns the straw bale wall. In the in-fill method (see picture), usually a wood post-and-beam framework provides support (although some builders have used Durisol or Faswall blocks), and the bales are used exclusively as infill. Often they wrap outside the posts, keeping the posts warm and free from condensation. The infill methods allows more flexibility in design, permitting taller buildings, and is considerably easier to obtain approvals for from local building inspectors. Various kinds of roofs can be applied, with some also incorporating straw as ceiling insulation.

Besides being strong and insulating, straw bale walls are surprisingly fire-resistant, especially when fully plastered on all sides. The great enemy of straw bale construction is moisture, and much attention is devoted to proper design of the building's "hat and shoes"—i.e. roof and foundation. If properly designed, straw bale structures will last indefinitely in even the wettest climates. But proper drainage and flashing details are essential, as is the protection of the bales from rain before and during construction. The clay in earthen plasters has been discovered to have a preservative effect when used with straw. A quality plastering job is also necessary to prevent pest infestation—which in any case tends not to be a major problem in straw bale buildings. Because it is such a new form of construction—and a popular one—straw bale building is in constant change (Magwood & Mack, 2000). New tools and techniques are developing each year, and debate rages about various aspects of construction and design among its builders. (For example, concerning the comparative merits or demerits of cement stucco and earthen plaster.) There seems to be little doubt, however, that straw bale construction is a building form of the future, and one that can easily be combined with other modes in hybrid systems.

Earthships

Earthships are a form of construction that stretches the definition of "natural" building while maintaining true to its spirit. Developed by New Mexico architect Michael Reynolds in the late seventies and early eighties, earthship construction makes good use of a plentiful local material—old tires—in an integrated design that also incorporates passive solar, earth-berming, photovoltaics, and water-conservation. It is a form of autonomous or "off the grid" housing, and an expression of one of the most radical and holistic philosophies of ecological living (Chiras, 2000).

Most of the public attention given to earthships focuses on their walls made of "engineered rubber-encased adobe building blocks"—that is, old car and truck tires pounded full of dirt from the excavation (Ehrhardt, 2002). The walls of stuffed stacked tires are plastered or stuccoed, creating an incredibly strong, earthquake resistant, fire- and termite-proof structure. The tire walls, oriented to the sun and earth-bermed on the north side, provide the great thermal mass that is the basis of its energy-efficiency. The earthship is, first and foremost, a thermal mass building, and secondarily, a passive solar building. Earthships are touted as providing "comfort in any climate" by designing a specific balance of mass and insolation that is appropriate to the climate in question. The Potter earthship near Bancroft Ontario uses only a small wood stove as supplementary heat periodically during the winter months (Berczi, Minke, & Sheen, 1996). The tires, encased in earth and plaster, do not emit harmful substances into either the air or the soil and water table, and are a building of choice for many chemically-sensitive people.

The structure of the classic earthship, designed by Michael Reynolds and his company Solar Survival Architecture (SSA), consists of two parts: U-shaped living spaces or earthship rooms, and an environmental interface corridor oriented to the sun (see drawing). The U's are shaped by packed and plastered tires, but the rooms can be closed off if desired for privacy. Flanking the building are two large water-storage cisterns that can hold up to 10,000 gallons of water. The front corridor houses the solar hot water and water purification systems; battery storage for the photovoltaic system; the kitchen and bathrooms; along with the planters that purify waste-water from sinks, showers and bathtubs (Chiras, 2000).

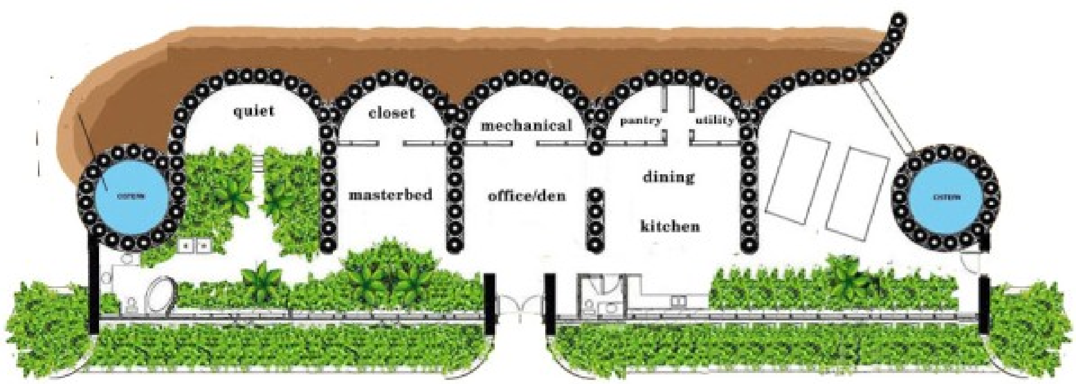
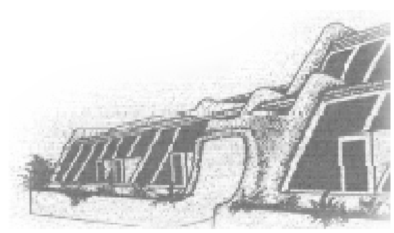


Figure 20. Typical Earthship Configuration
Source: Earthship Biotecture

All the earthship's water is harvested from the sky. Caught by the roof, it is channelled, via silt catches, to the cisterns which are sized to the local climate. A greywater system separates the toilet from other household drainage systems, allowing water to be used several times before being returned to the earth (Solar Survival Architecture, 2004).

Reynolds' earthship designs have had considerable impact on the green building movement. On one hand, the use of tires as a building material has spawned many different kinds of "tire houses" and earthship derivatives. On the other hand, its systems-design approach to autonomous housing has influenced builders who are using quite different materials. To optimize and generalize earthship benefits, Reynolds' firm has developed a number of "packages" and modules that are geared to different situations, building needs and budgets. SSA sells complete sets of plans, costing anywhere from US $1500 to $8000. The company has design strategies for luxury homes (like the most famous earthship built for actor Dennis Weaver (see figure 21), for low-cost affordable housing, and for whole communities of earthships—both intentional communities and subdivisions. It can meet the needs of both building professionals and DIYers.

Figure 21. Dennis Weaver's Earthship
Source: Earthship Biotecture



SSA also sells systems packages that contain preassembled components for the water purification, hot-water and solar electric systems—all contained neatly in a 5x8 foot crate that is simply installed on the front of the earthship. They then just need to be connected to the appropriate pipes and wires. The various modules designed by Reynolds and his colleagues for both building and services are appropriate for many kinds of remodelling and retrofit.

As with any type of building, there are possible disadvantages and dangers with earthships, and some arise from the very ambitiousness of their design. Earthships have, for example, been criticized as too unorthodox-looking and too esoteric to be readily accepted by local building departments. Their open design can present problems of privacy and interior noise, and their curved U-walls (designed for strength) can reduce usable space. Their many plants can cause humidity problems, and kitchens in the environmental interface corridor can sometimes be overly bright and hot in the daytime sun.

Many of these possible drawbacks are, however, being addressed in the evolving designs of both earthships and other kinds of tire- and hybrid-houses. Some newer earthship designs more readily fit in with conventional houses, with more familiar roofs and facades. Some architects, like Canada's Martin Liefhebber and David Sheen, are reworking aspects of earthship design to improve both aesthetics and functionality (Sheen, 2004).

One oft-cited disadvantage of earthships—the labour-intensity of the wall-building process—is, in my view, actually a strength. It is a building form that encourages owner and community participation. In our current economy that discourages, and even penalizes, informal economic activity, this can present some challenges. But in developing a built-environment that is more people-intensive and less resource- and capital-intensive, this is a plus.

The earthship is clearly a building form that makes great strides toward transforming buildings from passive consumption units, burdens on the environment, to active producers, harmonizing with nature's systems. Besides reducing material and energy throughputs, earthships make good use of local materials and contribute in many ways to household, community and regional self-reliance. They set an important example by looking to transform “waste” into a resource. They combine simplicity with a technically sophisticated adaptation to, and mimicking of, natural systems. And, with a quarter-century of experimentation behind them, they are now a proven technology, able to be accepted and implemented on a much wider scale.

Timber Frame and Stone

Some natural building forms that have served humanity well for millennia still have a place in the contemporary green building movement, but one that is limited by scarcity. Wood and stone can play a part in sustainable building, but both are building materials that cannot be used indiscriminately today.

Over the centuries, all northern forested regions developed timber framing traditions. They were appropriate technologies that married plentiful local materials with deep levels of craft. In many cases, the lumber used came from trees taken from the building site. Infill was usually some mixture of straw and clay, and roofs were comprised of thatch or stone—materials that often constituted the farm’s waste products. Whether they were simple houses, or magnificent Shinto temples or Scandinavian stave cathedrals, they proved eminently durable and beautiful (Chappell, 2002).

Today, as discussed in chapter III, wood is an endangered renewable resource. In particular, large dimension timbers are relatively scarce and often sourced from endangered old growth forests. The green building movement prioritizes the use of smaller dimensional lumber and the fabrication of trusses and beams from waste wood and small stock. In many cases, the concern is how wood is being used. A conventional platform-frame building can use up to eight times the wood that a post-and-beam structure does. Thus timber frame building can actually serve to conserve rather than exhaust wood stocks if it is used instead of conventional framing. But even here, many green builders are fabricating their posts and beams from smaller stock, or using engineered wood. Ecological timber framers who employ traditional craft techniques try to source their wood from sustainably-managed forests. Using wood sustainably is easiest for owner-builders who can harvest their own woodlots.

Stone was one of the first human building materials—in the form of caves, which have been called “stone buildings by subtraction.” Since then, we’ve used stone “by addition” for houses, cottages, barn, churches, castles, walls, aqueducts and walkways. It is among the most durable and beautiful of materials, and has also been associated with high levels of craft (Smith, 2002b).

Like wood, stone has its appropriate place in contemporary building, but other environmental considerations factor in to limit its use for building structures. Unlike wood, stone is ubiquitous. But it is heavy, and very difficult to gather and transport—a limitation even in a green economy that encourages people-intensive building techniques. Even more importantly, however, stone is a poor insulator, and thus stone buildings are major energy sinks (Chiras, 2000). There are ways to add insulation to compensate, but these measures add costs and resources that might be saved by the use of another primary building form. Stone buildings also require more substantial foundations. Thus, while stone may not be scarce, its use may require unsustainable use of other scarce resources (Smith, 2002b).

Despite the environmental limitations on the use of stone and timber, they must be included in any discussion of natural building because of the central role of craft and selfbuilding in a potential green economy. Natural materials tend to be those close at hand, and they are therefore dependent on the specific building situation. Many owner-builders may have ready access to timber and stone, and ways to utilize them in an ecological fashion. In timber-framing and stone masonry, humanity also has a vast reservoir of craft knowledge and experience, which is as much a spiritual resource as a material one. Stone and wood are almost primordial substances as far as the human experience goes, and one should not underestimate the importance of preserving, and even extending, our knowledge of them.

Cordwood Masonry

Cordwood masonry is a form of construction that combines the appeal of wood and masonry together. Short logs of wood are stacked up firewood-style in mortar that contains an insulating space in the centre. It is a resource-efficient method of building because it can use so-called “junk wood” that can’t be milled. Log lengths, and therefore wall thicknesses, range from 8 inches (200 mm) to 24 inches (600 mm). If cob is used for mortar, cordwood masonry can be a very inexpensive mode of wall-building in forested regions. Insulation cost—typically for lime-treated sawdust—is also fairly low. Cordwood masonry walls have great environmental appeal because they combine properties of insulation and thermal mass. They also have great aesthetic appeal, combining the warmth of wood with the texture of fine stone masonry.

Experts are uncertain about cordwood masonry’s origins, tending to feel it had multiple independent origins. Historical remains have been documented in Siberia and northern Greece around 1000 A.D. North American findings date back almost that far—

to buildings in Newfoundland probably of Viking origin. Modern origins date back to the mid-1800s in southern Wisconsin, the Ottawa Valley and along the St. Laurence River in Quebec. The current revival, as with other natural building forms, began in the 1970s (Chiras, 2000).

There are three main methods of cordwood masonry building. The first is the infill method utilizing a post-and-beam framework, similar to that of many straw bale buildings. The second is "stackwall" construction, historically popular in Canada, in which the corners are built first—out of regular cordwood units called "quoins" which are criss-crossed on alternate levels—and then the sidewalls are built in between in the normal way. The third method is the curved wall or roundhouse method. This, like stackwall, is also a load-bearing method where the whole wall is built like stackwall infill, with the curvature of the wall providing stability (see figure 22).

Figure 22. B.C. Cordwood Walls under Construction
Source: Earthwood Building School

Throughout most of the revival period, cement-based mortars have been used in cordwood building. In recent years, however, there has been more experimentation with cob-based mortars, which makes the building ever more ecological, but requires careful attention to getting the right mix (Roy, 2002). Wood selection and preparation are also factors. Cordwood construction allows great variety, and rule number one is usually “use what you’ve got”. But if there is a choice, lighter airier woods such as white cedar, spruce and poplar provide more insulation and more stability than more dense hardwoods. The wood should be well (air-) dried, and thoroughly debarked—since bark can harbour organic material that can cause decay. Typically the logs are not coated with a moisture barrier, but are allowed to breathe naturally. Sometimes other materials are included in the mix, such as bottle ends that would permit light to enter the wall (Roy, 1992).

Cordwood masonry is a good building form for community development and owner-building. It is labour-intensive but fairly simple. It is more energy-efficient than most earth-building modes, with buildings tending to be warm in winter and cool in summer. Cordwood buildings utilize wood waste, but they do require enormous amounts of wood, especially the post-and-beam method. If using cement mortars, one also increases the embodied energy of the building. And while durable, cordwood masonry tends to require a fair amount of maintenance, especially after a year or two, to seal shrinkage or expansion cracks. None of these drawbacks seem overwhelming, however, and in northern forested climates like much of Canada, cordwood provides an appropriate building form to nurture and generalize. For the right situation, it can be an economic and sustainable choice.

Bamboo

Bamboo, although associated in the North American mind with the tropics, is a grass native to every continent except Europe, and has been used as a building material dating back to 3500 BC (DeBoer, 2002). The Chinese, Indians and Incas took advantage of its great tensile strength to develop the first suspension bridges. It was used to build boats; and in building construction it became a common material in the vernacular architecture of China, Southeast Asia and Central and South America.

Bamboo is a very versatile material, used for food, furniture, musical instruments, cloth, paper-making and even rayon (Adams, 1998). Besides boats, bridges and buildings, it has been used in airplanes, kites and zeppelins; and Thomas Edison even used carbonized bamboo for the first successful light filaments. In building construction, it has served as framing, roofing, flooring, wall matting, ceilings, scaffolding, boards and panels, plywood, concrete reinforcement, connecting stakes, and more.

Bamboo is abundant, renewable and fast-growing. Some estimate that over 35 million acres (14 million hectares) of the Earth's surface are covered with one or more of the 1200 to 1400 species of the plant (Chiras, 2000). 64 percent are native to Southeast Asia, 33 percent grows in Latin America, and the rest are in Africa and Oceania. In North America there are only three native species of bamboo, compared to the 440 species native to Latin America. But bamboo thrives in the US southeast, and some hardy species can even grow in New England and Canada (Barnhart, 1989).

Bamboo in buildings can help reduce the amount of wood, steel and concrete needed. As a substitute for wood, it can take great pressure off forests, and contribute to local self-reliance, since great quantities can be produced in small areas. It has great compressive and tensile strength, and has shown great resistance to earthquakes. New joining techniques developed recently in Columbia have made bamboo structures both stronger and quicker to build. Always used extensively in Asia, bamboo building materials are spreading worldwide—notably in Columbia, Costa Rica, Mexico, Nicaragua, Australia and France. In North America it is currently being used as a wood substitute for flooring in the form of tongue-and-groove laminated flooring boards (e.g. Plyboo) that look just like hardwood flooring.

Like all materials, however, bamboo is no panacea, and has its drawbacks. It deteriorates rapidly in contact with moisture and must also be protected from insects. It is also very combustible, and it requires different kinds of joinery skills than dimensional lumber. Certain (“running”) species of bamboo can also be quite invasive, and growers must be cognizant of the dangers of such fast-growing plants in non-native environments (DeBoer, 2002). That said, bamboo has great potential to expand the palette of natural building materials in most areas of the world.

Earthbags and Papercrete

The natural building movement is spearheaded by a renaissance of traditional building materials like cob, adobe, bamboo, rammed earth, straw and cordwood. Nevertheless, the popularity of tire houses demonstrates that the movement does not narrowly restrict itself to tradition, and above all sees the human imagination as its primary resource. Earthship tire houses, however, seem almost conservative compared to exotic new systems like earthbags and papercrete which have very quickly come to prominence. Earthbag—or sandbag—building will certainly not replace platform-frame construction in subdivision development soon, but it is a dramatic example of the creative building forms that are emerging, and will continue to emerge, in the natural building movement.

Civil engineers, archeologists and the military have long made use of sandbags for temporary walls, bunkers and flood control. But the real earthbag tradition dates back many hundreds of days to the early 1990s, when Persian architect Nader Khalili at the California Institute of Earth Art and Architecture (Cal-Earth) began teaching his "superadobe" technique of earth-filled bag construction. Prior to that a few German architects in the late sixties and seventies had experimented with sandbag walls, and in the late seventies, German and Guatemalan researchers experimented with sandbags in their research into earthquake-proof building systems. But it was Khalili's work that sparked the rise of an earthbag building subculture that is growing quickly and is making continual improvements in earthbag theory and practice (Kennedy, 2002a).

The technique is basically flexible-form rammed earth. It uses locally available soil, often right from the building site, to fill sacks made of burlap or polypropylene. The bags are laid onto the wall in a staggered fashion, like bricks, and then tamped, sometimes with two parallel strands of barbed wire laid between courses to act as a kind of mortar. The walls are then plastered or stuccoed. Earthbags can easily make domed structures, preferably pointed or catenary domes, and lend themselves to organic shapes. Usually the soil used to fill the sacks is similar to that used in rammed earth construction, with 5 to 25 percent clay content, and the soil slightly moistened. After filling, laying, tamping and drying, each earthbag becomes as hard as a rammed earth wall, even before plastering (Wojciechowska, 2001). Builders like Kelly Hart have found that replacing the soil with volcanic rock is a means of adding substantial insulation value to the walls—equivalent to that of straw bales (Hart, 2002). Hart's house also features a papercrete plaster, made up of a slurry of paper fibre with just a bit of Portland cement added, which "breathes" better than cement-heavy stucco.

Figure 23. Earthbag and Papercrete Building, Colorado
Source: Kelly Hart, Greenhomebuilding.com

Papercrete is also a structural material that can either be made into blocks for wall construction or poured into forms. Although patented back in 1928, it fell into disuse until around 1990 when Eric Patterson of New Mexico and Mike McCain of Colorado began experimenting independently. Papercrete makes excellent use of waste paper, simply by pulping it and mixing it with water and cement. Because it absorbs water (but without expanding) it is probably most suited to dry regions, but it is an example of imaginative use of local and waste materials (Solberg, 2002).

A related material is fidobe—short for "fibrous adobe"—made by using adobe dirt in the slurry instead of cement. Fidobe weighs less than adobe, has much more insulation value, can hold a screw, and can be painted. By dispensing with Portland cement, it has even less embodied energy content than papercrete—although it dries much more slowly.

Papercrete and fidobe building is spreading rapidly, with new more convenient mixer and pump designs starting to appear. Plans for commercial production of papercrete blocks are also being discussed, which when realized should increase its use dramatically.

Earthbag construction is growing even more rapidly than papercrete, with the technique often being combined with other natural building systems, like straw bales and cordwood masonry. It is one of the best examples of the imagination and experimentation taking place in movement, and also how aesthetics and community spirit are being applied in materials development.

The Future of Natural Building Materials

This chapter has touched on only the smallest sample of the natural building movement and its materials. Many of the world's thousands of indigenous and vernacular building traditions could be included in this renaissance. Hybrid systems combining a number of the above materials are being improvised on a monthly basis. And because I have chosen to focus on wall-building systems, I have not emphasized the growing popularity of natural building products and systems for flooring, roofing, insulating, sealing, etc.

That said, a question remains: especially given the eccentric fringy look of so many cob cottages, earthships, and cordwood dwellings, how big can the natural building movement become? Is it a harbinger of future sustainable building or a faddish hippie subculture doomed forever to the margins?

Only time can answer these questions definitively, but if we refer to the principles of ecological design emphasized throughout this dissertation, I believe we must recognize, at very least, that the natural building movement is playing an important role in actualizing these principles. There can be no doubt that real sustainability depends upon much greater integration of formal and informal sectors; on more emphasis on resource- than on labour-intensity; on greater use of regionally-available resources of low embodied energy; on decreasing use of toxic petrochemical-based synthetic materials; and on greater participation of people in designing and adapting their built-environments.

Like other social movements concerned with creating alternatives, the practices of the natural building movement might seem so fringy and exotic only because mainstream building practices have become so removed from sensible ecological practice. If this is the case, then we can expect to see a growing convergence of natural building and mainstream green building. If we look closely, we will, I believe, find that such a convergence is already taking place. Certain kinds of natural building systems like straw bale are being found in more conventional settings, and natural building systems are slowly being accepted by local building officials. Natural materials, like bamboo flooring and strawboard, are also being found in conventional housing.

If our own economies are to survive, they will increasingly have to incorporate full costs into market prices. If this really happens, it will undoubtedly begin to transform the labour/materials intensity balance, making labour-intensive building forms more attractive, while forcing greater use of local materials. Already there are some macro-economic factors that are making natural materials more desirable. Green building assessment systems like LEED, for example, are evaluating buildings on the basis of life-cycle assessment (LCA) of their materials. Some governments are starting to insist that their buildings be LEED-certified, and so industry is expanding its investment in greener production. As LCA becomes the basis for the production of more and more materials in mainstream building, there will be a growing convergence of conventional and natural building.

Growing popularity of natural building is also likely to encourage it to become more like mainstream building in some ways. Fewer and fewer builders should be forced to do their own earth mixing, construct their own forming systems, manufacture their own blocks and bricks, and improvise their own tools. The new infrastructures and technologies to support natural building need not dilute the self-help nature of many of these systems. They may, in fact, make building *more* accessible to average people. Some of these new infrastructures may in fact serve to support the community fabric since today a fair amount of natural building is carried on by enthusiastic individuals in remote areas. Especially if we start to be successful in greening cities, urban areas currently colonized by the automobile can be fertile sources of natural building materials. Another factor may be progress toward sustainability in the underdeveloped world where, in some cases, the renaissance of traditional building methods is already well advanced and which has influenced the movement in the richer countries—especially in bamboo and various forms of earthen building (Kennedy, 2004).

Finally, it must be recognized that the “counter-cultural” character of much of the natural building movement may be one of its greatest assets. It is a realm where people have put their (non-monetary) values in command and actually worked to shape their work, their technology and the built-environments to reflect those values. Questions of consumption, end-use and voluntary simplicity have been intimately connected with concerns of production. Questions of technology have also been inextricably intertwined with respect for indigenous and traditional cultures, and the need for a sensible and regenerative combining of old and new, tradition and innovation, vernacular and scientific.

These questions of value, of want and need, are actually strategic economic development questions that are central to transformation of materials use in the entire economy. In the next chapter, I will look more specifically at questions of consumption that can be driving forces in economic transformation.

CHAPTER VI: CONSUMPTION
GREEN CONSUMERISM, LOCAL MARKETS AND BIOREGIONALITY

Regenerative Consumerism

An ecological economy requires changes in consumption as much as in production. Most discussion about consumption and environment, however, remains fairly superficial—usually focused either on reducing consumption, or on selection of higher quality products. In fact, ecological economics requires a basic transformation in both the character and organization of consumption. As discussed earlier, this involves the redefinition of consumption in a more non-material way, as services to meet well-defined needs; and also its reorganization to assure cyclical flows and the elimination of waste. Reduction and quality are essential, of course, but they can only be sufficiently achieved in the context of a more basic transformation of the purpose, content and organization of consumption.

Many social and environmental commentators react sceptically to the idea of consumption being so central to economic reform, and for good reason. A common tactic of the industrial establishment is to deflect responsibility for social and environmental improvement onto private consumers, thereby avoiding essential changes in production and regulation. This kind of preoccupation with private consumerism is simply a means of subordinating consumption to production, since it does nothing to deal with the basic "production-for-production's-sake" (accumulationist) character of the economy. It entails restricting the very definition of consumption, and limits consumer choice to what producers choose to provide. Ultimately, however, real changes in production begin with questions of consumption because these contain the most fundamental considerations of "end-use" and the very purpose of the economic activities. Truly prioritizing consumption issues would transform production and regulation. In the realm of consumption lay the most basic questions about the nature of economies.

In a partial but pragmatic way this is reflected in the evolution of environmental policy in the capitalist world. In Europe, where environmental awareness is greatest, there has been a shift from a focus on industrial pollution control to bringing about more sustainable consumption patterns, though "soft policy" instruments like eco-labelling (Jordan, Wurzel, Zito, & Brückner, 2003). Interestingly, this has been accompanied by greater concern with product design and stewardship, dealing with pollution in a more fundamental way (Charter et al., 2001). A related development has been the emergence of research and design of "product service systems" (PSS) geared to serve human needs with minimal resources (Mont, 2002b).

Europe is far from ecotopia, however, and the movement to more market-oriented "soft" instruments has also been partly encouraged by neo-liberal market-oriented forces in capitalism that seek to avoid substantive regulatory changes. In this chapter, therefore, I want to summarize some of the key questions relating to consumption and look at some of the main instruments to transform consumption and help leverage change in the entire economy. It must be emphasized that positive consumer action is not a substitute but a starting point for essential changes in production and regulation.

New forms of regenerative or transformative consumerism generally meet the following criteria:

- they exhibit an awareness of positive ecological alternatives, and go beyond simply protectionist concerns.
- they decrease material consumption, and make it more cyclical
- they overcome the social isolation of the individual consumer, and in doing so often actualize the potential of the consumer as a producer, or "prosumer".
- they are regenerative of humans & ecosystems, at least implicitly. They tend to encourage social justice, quality of work life and the integrity of natural systems.
- their impacts are not limited to final consumption but ripple upstream to influence extraction & processing, and downstream to affect disposal.

It is worth emphasizing the collective character of much regenerative consumerism. The sharing involved is not some anachronistic remnant of tribal or state-socialist societies, but an expression of design intelligence in postindustrial development. New forms of sharing—as expressed in co-housing, eco-industrial networks, car-sharing, renewable energy co-ops, product leasing, etc.—can make possible vast resource savings by increasing the intensity of use of tools, spaces and infrastructure. Most forms of reuse are basically a kind of sharing. Such sharing not only reduces environmental burdens, but increases quality of life by de-isolating people. And, as we will see in the creation of community market-power, it also empowers people economically.

Information, Isolation and the Limits of Private Consumerism

The growing focus of capitalist environmental regulation on consumption patterns is to be welcomed. But even where these initiatives are connected with product design, "integrated product policy" (IPP) and eco-service development, they are unduly limited if consumption remains defined as an individual act. There is a growing literature not just critiquing individual consumption as an alienated and destructive aspect of capitalism, but also criticizing various forms of consumerism, like green consumerism, as an avoidance of basic change.

As mentioned above, most green consumerism has little or no effect on the productivist and accumulationist driving forces of the capitalist economy. Even when one can trust the product evaluation, there is also no guarantee that the sale of green products results in a corresponding reduction in sales of "brown" products. Green products might simply constitute more luxury add-on niche markets for those who can afford the products.

Then there is the whole problem of information and knowledge. It is interesting to look at the development of information and eco-labelling programmes directed at private consumers over the last 20 years. Even in Europe, where awareness is greatest, there is a definite reticence of governments and corporations to put sufficient resources into developing these programmes. The most successful of the eco-labelling programmes, Germany's Blue Angel, has declined somewhat since the late nineties, and the European Union's scheme is growing very slowly. In many places like Canada, eco-labelling initiatives have not prioritized consumers, but rather company-to-company transactions. And most companies, for their part, have recoiled from labelling of any sort as a limitation on their managerial prerogatives—as demonstrated in recent struggles over the labelling of genetically-modified foods.

There are a number of factors involved here—which would be too much to explore exhaustively in this paper. But a very basic one, which has great relevance to creating new forms of green consumerism for building materials, is the central role of ignorance in the modern consumer (or waste) economy. This is a topic discussed in my previous book and by writers such as Robin Murray (1993), who argues that the postwar Fordist economy depended as much on the de-skilling of consumers as on its well-recognized de-skilling of mass production workers. The structural crisis of effective demand which was at the heart of the Great Depression has shaped the cultural, educational and media environments of late capitalism, prioritizing economic growth and undifferentiated consumption above everything else. Advertising has penetrated almost every area of culture, and most uses of information in popular culture are in some way connected to selling. In spite of its positive potential, even the Internet has become a means of distributing ignorance and half-truths, encouraging and confusing consumers more than ever.

There have been a number of narrow academic studies in the past decade examining why consumers have not embraced green consumption in a bigger way. Almost all of these studies psychologize consumers, oblivious to the powerful institutional forces encouraging blind consumption and deliberately distributing misinformation. They miss the fact that, in many respects, consumer cynicism is an understandable reaction to an economy of manipulation and mindlessness.

To the degree that individual consumption choices can be a force for change, a supportive information infrastructure must be organized to guide consumers. But even in environmental circles that emphasize the importance of individual choice, there is little support provided to guide those choices. Brower and Leon (1999) point out that much of the environmental movement promotes a righteous moralism that suggests that all consumer choices are equally significant—be it use of paper towels, disposable diapers or cars. The implication is that radical voluntary simplicity is the only environmental option. Brower and Leon argue, however, that all choices are not equal and that environmentalists should provide priority lists for conscious consumption—highlighting the actions that can make a great difference without the time and commitment intrinsic to voluntary simplicity. Their book, *The Consumer's Guide to Effective Environmental Choices*, does precisely that, highlighting transportation, food choices, and household operations (like heating) as the top three high impact areas of private consumption.

In summary, even on the level of individual consumerism, whether it is green or fair trade consumerism, there must be a collective dimension, at very least an "information commons" where individuals can obtain accurate reliable information on consumer products. Ideally this information environment should be connected to local labelling programmes and associations of green enterprise. In this context, individual green consumerism can merge into community initiatives to create new kinds of green markets and local green industry.

Community Consumerism: the Green Communities Initiative

While even the most private green consumption requires an information infrastructure, there are more explicitly collective strategies that can play a major role in community development and in transforming the role of materials in building. Some of these strategies are closely related to consumer boycotts. But here I am mainly concerned with forms of collective consumerism more directly connected to positive forms of green economic development: renewable energy co-ops, car sharing networks, community-shared agriculture groups, co-housing developments, etc. Compared to most forms of individual consumerism, the above forms of collective consumerism tend to be defined much more broadly than as “consumer” organizations. In fact, many of them are equally production or service organizations, and herein lies an important lesson about regenerative consumerism: it tends to contribute to greater integration of production and consumption.

For building materials, one of the most powerful models for community consumerism comes from the Green Communities programme in Ontario in the early 1990s. It combines elements of the ESCO, or energy service company, with green consumer information on materials, with green market and job creation.

An ESCO is an organization that provides building retrofit services for “free”, or rather seemingly for free since the work is paid for by the savings attained in the retrofit. The Green Communities Initiative (GCI) originated in the Ontario environment ministry, but really consisted of a network of community groups in ten Ontario communities. Their concerns were broad, but their core efforts revolved around increasing the energy-efficiency of residential and small commercial buildings—and in generating substantial local economic activity in the process. As non-profit community groups they were not in themselves ESCOs, but employed a similar philosophy of generating prosperity through savings.

A complementary project of the Toronto GCI group, in collaboration with the Community Economic Development Secretariat of the (NDP) provincial government, was the compilation of a guide to green products and services. The guide was intended to be given to building owners by “home greenup” inspectors who would first make recommendations to owners about measures to reduce their energy and materials consumption. All products and services to be listed were well-researched by local activists and academics, and certified according to criteria that included social as well as environmental factors. Potential consumers of the directory-listed products could be assured that their consumption would go toward supporting legitimate local green businesses, and that economic benefits that would stay in their community. And, because of the linkage with the building audit, they could also be sure that their consumption of certified building products, appliances, etc. would result in a *net reduction* of resource consumption.

The project unfortunately was aborted in June 1995, just as the first directory was completed and printed for distribution, due to the election of a right-wing provincial government. Some elements of the project are slowly being reconstituted by now autonomous community groups, but some other crucial plans for the directory project must be mentioned. They involve green market creation. The intention of project designers—Robin Murray and Keith Collins—was that it could create a cohesive green market that could potentially wield substantial influence on industry. The Home Greenup project entailed thousands of home visits a year. The recommendations of the inspectors were accompanied by a list of certified green contractors for various kinds of building retrofit and renovation—who would derive substantial business from the recommendations. But through the products directory, the audits might translate into big sales for manufacturers of listed building products. And such a guaranteed market might give the community power to request the (local/regional) production of particularly desirable items—a no-VOC paint, a non-PVC weatherstripping, etc.

Murray and Collins also hatched an arrangement with local credit unions to issue special discount cards (called "eco-cards") along with directories, which would enable card-holders to obtain discounts on listed products and services. The cards would be "smart cards" whose swiping would record important information on green purchasing patterns, which would be another enticement for manufacturers, and another bargaining chip for the community in influencing their own economic development. This combination of an information infrastructure, consumer cooperation and green enterprise would constitute a powerful complex of community development.

Once established, the possibilities for generating other developmental connections would have been endless. Besides building materials, the directory also included sections on food, appliances, heating equipment, sustainable transportation, and recycling—providing opportunities to dovetail projects with a range of Ontario environmental and c.e.d. groups. In the realm of building materials, however, plans were already being made to influence mainstream materials retailing in Toronto. As the first draft of the directory was being completed, local building material retailers were approached about the possibility of their stocking the green materials listed in the directory. Some expressed strong interest in ordering them, in exchange for being promoted as “the green building centres in Toronto”. The plan was to locate small computer kiosks in the retail stores. Consumers who wanted to find the right green product for their particular job would thus have the entire green materials database accessible in a user-friendly format. At least one of the building centres was also eager to become an educational centre, featuring how-to workshops using environmental materials.

The fact that these goals have not been realized in Toronto in no way discredits their feasibility. The projects never failed—they were simply not implemented, as environmental and c.e.d. groups were put on the defensive over the next several years by a conservative government driven by a slash-and-burn corporate brown industry agenda. Over that time, a surprising number of green alternatives were established incorporating elements of community consumerism: the Toronto Renewable Energy Co-op (TREC), Toronto AutoShare, and a number of food-related initiatives connecting rooftop and community gardening, affordable nutrition for the poor, local farmers markets, etc. But opportunities in the realm of green markets for building materials have still not been exploited, despite some abortive efforts (notably one by the Design Exchange) to make a directory of green building materials available.

Information, Value and Green Markets: the SPPC

Another example of the combined power of information and collectivity is the *Sustainable Products Purchasers Coalition* (SPPC). Although based in Portland OR, this is not exactly a community initiative but one that combines the clout of its membership with technical expertise to encourage companies to employ life cycle assessment (LCA) and make public LCA data on its products. Its diverse membership includes NGOs, companies, and government agencies—notably from cities like Portland, Seattle and Santa Monica CA. The Coalition's main goal is to "provide a standardized form in which manufacturers can provide Life Cycle data for their product compatible with the variety of accepted LCA tools currently in use in the industry." (Sustainable Products Purchasers Coalition (SPPC), 2002). It provides market research to manufacturers who want to tap the market embodied in the Coalition. The SPPC is advised by a committee of LCA experts which develops criteria for life cycle data and LCA results that push environmental boundaries but also fall within the profitable capacity of manufacturers. Through its reporting forms, it synthesizes LCA information on a wide variety of products including building materials, office products, cleaning products, automobiles, furnishings and more.

The SPPC is not a purchasing group, but an advocacy group that seeks to "demonstrate to manufacturers that there is a strong and vocal community of purchasers that buy sustainable products and are seeking reliable, standardized environmental data on sustainable products". Through its website, the SPPC publishes stats on its total aggregate purchasing power and hosts a forum for members to discuss sustainable products.

The SPPC is a fairly new organization, but it represents a model that could be applied in various situations. On a local and regional level, this kind of organization could be networked with NGOs (like the GCI), CED groups, green building associations, community indicator projects, university departments, and municipal economic development agencies. It could also be vital source of information for local media on sustainable economic development, environmental health, etc.

Building Supply Retailing

The role of building supply retailers is a crucial one in the transformation of materials use in building. It is the point of connection between producers and end-users, between production and consumption. In the existing economy, it is a place geared to pushing out as much stuff as possible. The question is: in an ecological economy that is based in the selling of services, what would an “ecological lumberyard” look like? Undoubtedly very different than existing ones. Despite the growth of the green building movement, easy access to ecological materials is one of the major problems of environmentally-minded builders and designers. But the retail landscape for building materials is multi-levelled, with different challenges at each level. Here I will focus on general retailers, as opposed to specialty producers that retail directly to the public. The latter are increasingly numerous, and their growth is made more possible by Internet marketing, but it is general retailing that is of more strategic concern for community development.

Among generalized retailers, there are (1) those that sell exclusively green products; (2) conventional building supply retailers who are consciously trying to increase the number of green products they carry, and who strongly promote ecological products; and (3) large mainstream building supply retailers who are responding variously to regulatory pressure, market demand and the growth of the green building industry.

As of 2004, there are probably fewer than a score of building supply retailers in North America committed exclusively to green materials. Most of those are small and concentrated in a few regions—particularly the Pacific northwest, California, and Colorado. Most tend to focus on certain kinds of materials like flooring, interior finishes, and healthy-home products for the environmentally-sensitive. Some, however, like New York City's *Environmental Construction Outfitters* and Seattle's *Environmental Home Center*, handle a surprising range of products, including reused materials, and have a conscious orientation to local community development and the green building movement. Most have growing mail-order and Internet sales departments, and are involved in consulting and educational activity that complements their eco-materials work (Yost, 2001). Although these stores are still rare in North America, in parts of Europe, such all-purpose all-green centres are more common. Thus it is likely that they will be a wave of the future in North America.

More common are regular building supply retailers who have a positive attitude toward the green building movement and try to stock what they can of green building supplies. An especially enthusiastic example is Central California's *Hayward Lumber*, founded in 1910, led by fourth generation president Bill Hayward, which has seven lumberyards and four design centres, and employs 450 people (Hayward Lumber, 2004). Although green products constitute less than 10 percent of their sales, they are aggressively developing demand through green educational marketing efforts. Like the smaller all-green outfits, Hayward is an active member of green networks like the US Green Building Council (USGBC) and the Forest Stewardship Council (FSC). Although Haywood is somewhat unique in its environmental awareness, this level of enterprise has perhaps the most potential for transforming retailing—"mainstreaming green" through active involvement with the green building professionals and community development activists. "Community consumerism" initiatives like the GCI project discussed above find the most fertile ground for collaboration with medium-sized community-oriented retailers like Hayward.

Green retailing has major challenges to face in the case of the third main category of retailer: the large retailing chains, and in particular the "big box" outfits like Home Depot, Lowe's and Rona. The challenges and contradictions of the green movement in dealing with these corporations are similar to those faced by the wood certification movement in dealing with large corporations. On one hand, big corporations have the power and resources to affect the entire economy quickly. On the other hand, the very nature of this mass retailing seems intrinsically antithetical to closed-loop community-based economic development.

Home Depot has had an environmental programme since the early nineties. It has opened recycling depots at a few of its stores; developed an "Environmental Greenprint" educational pamphlet demonstrating how people can cut energy consumption and waste in their homes; instituted a car-pooling programme for its Atlanta employees; incorporated more use of recycled materials in its own office operations; and established a six-figure grant programme to donate to small ENGOs. It also tweaked its product line, dropping lead plumbing solder, and introducing a more environmentally-friendly paintbrush cleaner (Home Depot Inc., 2004). Its biggest move came, however, after years of pressure and protest from environmentalists. In 1999, Home Depot agreed to stock FSC-certified wood in all its stores. This was a major victory for sustainable forestry and political consumerism.

Such gains, however, should not obscure some inherent difficulties with the big box retailers. Compared to their total volume of sales and profits, their environmental measures amount mainly to greenwashing and public relations. There are definite limits to how far they can go to green their product line, since their very economies of scale discourage the use of local resources and the establish of tight closed-loops. Most importantly, they encourage urban sprawl and tend to suck capital out of local communities, putting undue pressure on more community-based firms (Yost, 2001).

Nevertheless, they are susceptible to small changes in demand, and so somewhat responsive to public pressure. Community, environmental groups and green builders are probably wise to develop an "aikido strategy" of working with and redirecting the development of the big box retailers, while at the same time seeking to create more space for local green retailers. To do this, green labelling and directory programmes have to be better developed, and action on reuse and deconstruction advanced. Local economic measures also have to be instituted to make sure that capital and jobs remain in the community. If the big box retailers are to survive in green communities, they will have to evolve into true community businesses—possibly a contradictory and impossible task. Even in a green economy, certain economies of scale will be useful and desirable. But the essence of big retailing today is growth and low-price. If full costs were to be fully incorporated in product prices, could the big box retailers survive? If incentives for quality of work life, dematerialization of production, and standard of living were implemented in regional economies, would Home Depot have a place? In a construction industry increasingly concerned with deconstruction, design for disassembly and local resources, what would the big retailers do?

Building Centres as Conservation Utilities

Ultimately, the metamorphosis of construction into an eco-service industry depends upon fundamental market changes that would build full costs into market prices. Prices for virgin materials have to increase substantially, especially compared to labour costs and the costs of reused or reclaimed materials. Fully internalized transport costs would encourage greater use of local materials, and help undercut the power of the big box chains. For this price revolution to happen, conscious government action will certainly be necessary—in the area of taxes, subsidies and producer liability that can make “prices tell the ecological truth.” (In the next chapter, I will touch more explicitly on these policy actions.) As important as these regulatory actions are, however, there will probably have to be a maturation of grassroots pressure—and grassroots enterprise—to make these rule changes possible.

Despite their small numbers, the pattern for future retailing may be set by the all-green retailers in Colorado and Oregon that are combining new green product sales with used building material retailing, consulting and education. I believe this constitutes two key new dimensions of building materials retailing: (1) that of making building centres into ***used material depots***, and (2) that of making retail stores into ***information and learning centres***.

Used building material retailing is a natural fit for building supply outlets. If industrial economies are to make the transition to sustainability, the rapidly growing phenomenon of used material and salvage yards will have metamorphose into full-blown eco-building centres with a range of functions and services. They would sell used and reconditioned building materials, and even new products would be increasingly remanufactured or containing large percentages of recycled materials. They would be depots for purchase as well as sale of used materials, likely connected to resource recovery parks and close to repair and remanufacturing facilities. Perhaps most importantly, this would make them centres for deconstruction services—in the same way that some used building material retailers today already employ deconstruction teams.

The transformation of building supply retailers into education centres is a natural expression of postindustrial development—in which resources are replaced by information. This is particularly true in an economy where do-it-yourself activities are constantly growing as a portion of the economy. Lumber yards and building centres are logical places for workshops on materials, techniques and equipment. In fact, D-I-Y workshops are already a strong trend among retailers like Woodlands, Rona and Home Depot; what needs to be added is some environmental content.

There are some obvious challenges in this kind of transition, though. Currently educational activities are designed as ways to increase material sales, and are subsidized by sales. By rights, information should substitute for material sales, and yet it seems undesirable to charge for information and education. Income for retailers should be connected to material savings—through remanufacturing, deconstruction, education, eco-labelling and community indicator projects. Green taxes would be one way of discouraging maximum sales of products, especially if tax revenues were earmarked for conservation education.

Another variation on this would take off on Paul Hawken's ideas on conservation utilities (Hawken, 1993, p. 191-194). The utility is a combination public/private enterprise whose self-interest can be designed to correspond to the long-term public interest. In the realm of energy, green thinking has already spurred a new vision for electrical utilities formerly oriented only to generation or sales. It has proposed new kinds of market incentives for saving, and some of these incentives are actually being applied as part of growing concern with "demand side management." Hawken has proposed something similar for resources, more applicable to primary resources and extraction industry, as a means, for example, of stewardship of forest and aquatic resources. The idea could, however, also be applied to retail sales, since building material retailers are in a similar position to most municipal utilities (like Toronto Hydro) whose financial raison d'être has been to sell as much energy as possible.

Becoming a utility requires, however, taking on larger responsibilities, internalizing related costs, and developing new sources of income. Building centres could do that by combining material sales (new and used) with green building education, deconstruction services, inspections and audits, building retrofit services, etc. Tax measures could be a means of encouraging this. And EPR legislation closing loops and curbing disposal certainly would be. But many other kinds of structural incentives could be employed, reflecting the centres' roles in trades training, job creation, building certification, waste reduction, etc. Because of the enormous role of building materials in the economy, and because of its pivotal position in the community, the building centre should become, like the municipal energy utility (Milani, 2000, p. 128), a strategic institution of green community development.

Green Procurement

Another form of collective consumerism spans the gap between markets and regulation. It is the role of large organizations, particularly governments, in creating market demand through their purchasing decisions. All too often people make rigid distinctions between politics and economics, between the state and markets, between regulators and regulated. In fact, the state, especially since the Great Depression, constitutes a substantial portion of the economy, with government purchases in the developed countries amounting to up to 25 percent of GDP (Organisation for Economic Co-Operation and Development (OECD), 2000). In Canada, the federal government alone spends almost $12 billion on products and services, making it the biggest single buyer in the country (Government of Canada, 2003). As I discussed in more detail in my first book, the line between politics and economics is further blurred by the nature of large organizations and planning since the managerial revolution. As Bazelon (1963) noted decades ago, the modern corporation is not simply a producer, but a political-economic organization, an "industrial government" defined by its planning powers.

Green procurement presents some particular opportunities for economic change. Part of it is due to its quantity, but part is because of its character. It is, in a sense, more conscious, since institutional purchases are defined in detailed contracts with comprehensive specifications on the product or service being bought (Mastny, 2004). Not much impulse buying here—a far cry from buying by private consumers. If green values (or green movement political pressure) can be brought to bear on these specifications, the possibility exists for single decisions to effect quick and substantial boosts to green markets.

Although the very notion of green procurement is a recent one, there are already precedents and success stories. In the 1980s “buy recycled” initiatives were launched both to support the movement for recycled-content products and take pressure off landfills. Many of these policies were quite effective in stabilizing markets for recycled goods, supporting curbside recycling programmes, extending landfill life, creating jobs and more (Mastny, 2004). In Europe, where green procurement is more widespread, many green products, like paper, have eliminated the price divide that always made them more expensive compared to mainstream products. And this is at least partly due to the greater economies-of-scale encouraged by government purchasing.

By the early nineties, “buy recycled” had matured into a more generalized green procurement movement, as many countries—including Austria, Canada, Denmark, Germany, Japan, and the United States—implemented a number of national laws or policies requiring government agencies to buy green.

Institutional procurement, of course, involves much more than governments. The procurement decisions of a number of large corporations have had major impacts on green markets: including Bank of America (paper), Boeing (lighting), Nike (cotton), Federal Express (auto), McDonald’s (packaging), and IKEA and Home Depot (wood). Some of these decisions were prompted by political pressures forcing the internalization of costs. But most were also driven by some kind of self-interest, and often helped achieve substantial efficiencies or pay-backs for the corporations in question. Universities are also major institutional purchasers, in the US constituting nearly 3 percent of the country’s GDP (Mastny, 2004).

My particular concern here, however, is with government—not just because of its quantitative impact, but because of how state procurement policy dovetails with its environmental regulatory policy in affecting the entire economy. The simplest example is how governments can require that all products in a particular market have a certain recycled content. But green procurement can also be a major support to green job creation, waste management, energy conservation, etc.

The possibilities for this kind of multi-dimensional impact are greatest at the local level, where government procurement can also work in a complementary way with community consumerism, like that of the GCI. Not surprising, local authorities are leading the way in countries with strong green procurement initiatives (Erdmenger, 2003). This is particularly in Europe, but it is also true in North America for cities like Santa Monica CA, Seattle and even, to a lesser extent, Toronto.

According to Clement, Plas and Erdmenger (2003, p. 70) of the International Congress on Local Environmental Initiatives (ICLEI), which co-ordinates programmes around the world:

> Local governments are closest to the people—thus they offer the potential for the participation of interest groups within their boundaries, often even down to the level of the individual citizen. This does not guarantee, but increases the likelihood, that local politics will pick up the new ideas, that the implementation of decisions will be monitored more closely, and that administration will be held accountable. Local Governments are more adaptable/flexible than governments at national level. They are more able and willing to experiment and innovate. In all international examples of green purchasing activities, it was local governments who first instigated such approaches.

They add that local innovators tend to get recognition and learn quickly from others experience, key factors in innovation.

Building materials are a key component in local procurement. ICLEI's study of European cities found that spending on building construction and renovation was by far the biggest product group—constituting from 15 to over 35 percent of procurement costs. Municipal purchasing has been a key factor in increasing energy efficiency, reducing sick building syndrome, supporting markets for certified wood, and eroding markets for PVC and other destructive materials.

Procurement in green building is, however, a real challenge for municipalities because of the complexity of the product group and building process. In most cities building is the responsibility of a separate department over which the Central Purchasing office has little control. In some places, sustainable building sub-departments have developed within the building departments, and these have been useful in maintaining relationships with both city environment, energy and purchasing offices. In the mid-90s, Toronto was spurred primarily by concerns about waste to develop a GIPPER Guide to Green Procurement. GIPPER stood for Toronto's Governments Incorporating Procurement Policies to Eliminate Refuse, and its governing committee included representatives from Toronto area municipalities, Ontario Hydro, the Canadian Standards Assn., the provincial and the federal government. It included guidelines for the purchase of asphalt, brick masonry and tile; concrete; drywall and wood (City of Toronto, 1997).

The potential of local green procurement has, however, barely been tapped. As suggested by ICLEI above, local procurement takes place in a realm that is conducive to grassroots citizen participation and education. It can complement strongly action geared to private green consumerism, and especially to community consumerism that, like government procurement, attempts to create alternative market power.

City governments are in an excellent position to promote green labelling, perhaps even developing their own local labels. They are also in a good position to reorient university research toward knowledge necessary for green market development—e.g. in community sustainability indicators, life cycle assessment, geographical information systems for green market creation, etc. City governments also have the advantage of influence over municipal electrical utilities, water infrastructure, waste disposal charges, and the many forms of environmental regulation. Much more easily than higher levels of government, they can integrate their policies to support their complementary initiatives.

Grassroots Regulation: Information, Value and Green Markets

Green procurement dramatizes the de facto regulatory power of green market creation. But, as I will explore further in the next chapter, the marriage of knowledge and green consumer market power can constitute a new non-state regulatory force. Increasingly we are finding initiatives like organic food, green energy, sustainably-harvested wood, and green building certification systems. Many of these "voluntary market-based" initiatives actually apply standards that are far more rigorous than those mandated by government, and they are by no means limited to fringe niche markets. Green building assessment systems like LEED, for example, have begun to affect mass markets—just as organic food and wood certification have done now for several years. Green consumerism and green market creation, tied to comprehensive knowledge, can thus serve as the strategic pivot point for transforming the form and content of production, as well as the rules and driving forces of the economy. The effect of such market transformation is the creation of what Korten (1999) calls "mindful markets"—

markets driven not by the “invisible hand” of accumulation, but by social and ecological values carefully considered and by human and environmental need. It makes sense that such mindfulness emerges directly from the industries and professions affected, since they are most in touch with the potentials. Consumption and green markets are also appropriate starting points for green transformation because of the central importance of “end-use” in ecological design processes.

In the next chapter I want to move on to look more explicitly at regulation and regulatory trends to try to better understand how grassroots power based in ecological knowledge can affect and transform the ground rules and values of economic life, particularly as they affect building materials.

CHAPTER VII:
NEW RULES AND REGULATION:
EPR, SERVICE, SOCIETY AND THE STATE

Regulation and Development

Regulation is not a simple matter, either in our existing industrial economy or in a future green economy. Regulation becomes more complicated in complex economies, and economic and technological development are inevitably expressions of increasing complexity. This chapter will provide a concise overview of general regulatory tendencies and of current contentious issues in regulation, before moving on to consider progressive product policy for building materials.

In the early, or classical, industrial capitalist economy, regulation was a simple matter, at least in theory. The state was to stay out of the way and let capitalist markets do their job. In practice, such laissez-faire economic policies could really only work for the first or leading industrial powers, like Britain, followed by the United States. “Catch up” development always seemed to require strong state action, at very least in temporarily protecting vulnerable but vital sectors from the market power of stronger competitors. Nevertheless, while the theory wasn’t perfect, there was something about the nature of early industrial economies that shaped a pervasive separation between politics and economics, state and markets. This ‘something’ had to do with the material character of early industrialism, and also with the role of routine (cog-) labour in industrial technology. In *Designing the Green Economy*, I explored in more detail how the nature of production and labour in early industrialism (1) permitted markets to actually do a decent job in distributing resources, driving production, and facilitating innovation, and (2) limited what the state could do. In this chapter I will summarize some of those key relationships that are relevant to current issues and development potentials.

The main issue is the relationship between politics, economics and culture. They were very separate in early industrialism, with economics being the dominant realm. However, when culture and knowledge become key economic forces, economic development entails greater degrees of conscious direction, and politics must become ever more integrated into everyday economic affairs.

The Great Depression of the thirties forced greater integration, since it was ultimately a market system failure resulting from the rise of these new culture-based productive forces. Economically the failure was expressed in a structural crisis of overproduction (or chronic effective demand shortage) that discouraged economic recovery after the great crash of 1929. Greater political intervention was necessary to get the economy going, and to keep it from crashing again. Emerging productive forces not only made production more complex but since consumption (i.e. effective demand) could no longer be taken for granted, it too had to be more planned. The development of new organizational, management and informational tools made this increasingly feasible. In the postwar Fordist era, not only did the state become a major part of the economy, but corporations themselves became planning organizations, ushering in a new stage of managerial capitalism. Not incidentally, this was also the era of state socialist industrialism in Eastern Europe.

The legitimization of the market system required that this new post-Depression integration maintain a façade of political separation and market autonomy. In any case, this politicization was not in itself sufficient to remedy the chronic crisis of effective demand. Labour agreements, public works, and social safety nets were part of the new arrangements, but they did not guarantee enough demand. New forms of money and credit would help, but another element was necessary to provide demand—waste. War industry and suburbanization were the main pillars of the North American waste economy, and in tandem with Keynesian monetary policy, they were quite successful in helping create and sustain a 25-year long economic boom in North America.

The Fordist system started coming unglued in the 1970s due to a number of factors—the most important being the burden of waste, growing transnational corporate power, inter-capitalist competition, and technological change. Fordism's problems gave impetus to a growing chorus of criticism of regulation itself, or what its critics called command-and-control. The question remains, however, as to whether the integration of politics went too far, or whether it hasn't gone far enough.

The Corporate Attack on Regulation

All around the world, industrialism's old-line regulatory state is under attack. Complexity and knowledge-based development appear to beget decentralization, as centralization and excessive bureaucracy appear too slow and inflexible to respond to subtle and rapid change. As noted above, the crisis of Fordism resulted not just from the burden of waste, but also technological change. Tech change contributed to those decentralizing trends that have undercut bureaucracy and monolithic organizations everywhere—one of the main causes of the decline of state socialism.

There can be no doubt that Fordist command-and-control had its problems, and that its requirements could sometimes be expensive and inefficient. But many of its corporate critics and affiliated media and academia have argued that this constitutes a failure of regulation per se. They call for a return to unconscious market forces. Many of these critics, however, appear to be motivated more by another trend in industrial development that is consistently and often deliberately confused with postindustrial decentralization: economic globalization and the insistent push of corporations for freedom from social, environmental and political accountability.

This push has been made possible by the global extension of production and consumption loops, undermining many of managerial devices of national states. The information revolution has also spawned a giant new international financial economy that has also undercut governments' ability to regulate investment. Corporations see an opening and are using it to reduce (or even eliminate) values other than those of accumulation in the modern economy, a phenomenon known as "neo-liberalism". Despite the fact that both the technological capacity and the social movements *for* democracy are growing, potentials for decentralization are actually being used *to erode* democracy and accountability. Instead of broadening the scope for social and ecological values in the economy, states are being forced to abandon non-monetary values to pure (accumulationist) market values. And organizationally, governments are being pressured into supporting ever more extended economic loops, instead of closing them. Not only is this inefficient and wasteful, but it increasingly subordinates communities, regions and even nations to external forces.

Throughout the capitalist world, therefore, alternatives to “command and control” have been proposed for sometimes diametrically opposite reasons, and the state has sometimes responded to both positive and negative pressures with the same programmes. A “next generation” of regulatory techniques has emerged, including self-regulation, co-regulation, voluntary agreements, regulatory flexibility, negotiated agreements, environmental partnerships, informational regulation, and economic instruments. Many instances of these are expressions of a search for more positive forms of regulation that reward continual improvement, apply to specific situations better, and do it all in a “least cost” way. But sometimes aspects of the very same programmes are defensive concessions to a narrow budget-cutting bottom-line mentality that is starving governments of essential resources and undercutting the few remaining forms of “commons” left in industrial economies. Environmentalists have been justifiably concerned with an excessive preoccupation with flexibility and voluntary agreements that have had detrimental effects on communities and the environment. Many have insisted that the solution is the opposite: far more comprehensive and rigorous mandatory controls and direct government intervention. But there is another critique of command-and-control that takes a very different tack.

The Design Perspective on Regulation

From the fall of state socialism to decline of giant energy generation utilities, it seems clear that complex economies defy excessive centralization. It may be, however, that command-and-control has failed not because it takes political-economic integration too far, but because it doesn't take it far enough. That is, postindustrial productive forces—as well as real sustainability—may demand a greater extension of political consciousness into everyday enterprise, decentralizing and democratizing planning.

Command-and-control has been criticized from an orientation quite different from the corporate voluntarist line by green thinkers who represent what I've called the "design" perspective of green economics. They have diverse concerns and often use different terminology, and include Barry Commoner, John T. Lyle, William McDonough, Paul Hawken, Ken Geiser, Sim Van der Ryn, David Boyd, and David Morris, to name just a few. What they have in common are a larger vision of the economy's ecological potential, and an insistence that such a vision—based in principles of dematerialization and detoxification—must be the starting point for the design of the economy's incentives and disincentives. Unless this vision is present, they argue that neither command-and-control nor new market-based approaches will achieve real sustainability.

The main source of the eco-critics' concerns is not centralization or flexibility per se, but the fact that Fordist centralization was really set up to avoid more fundamental organizational and design changes (including changes in the purpose of many economic activities). Many of them recognize the contributions that post-Depression regulation made. It did introduce many non-economic and longer-term economic values into the economy; and many of these gains were possible only because of decades-long struggle by workers, women, minorities, the poor, etc. This was true even for environmental regulation, which evolved late in the Fordist era, largely prompted by the environmental destruction intrinsic to the postwar Fordist waste solution.

But, as with the postwar welfare state, command-and-control tended to be implemented as much to avoid fundamental solutions. In the 1930s and 1940s, when markets driven by accumulation failed to work, markets propelled by social and environmental need could have been fashioned, increasing the quality of life and free time, even while dematerializing production. Later on, with the rise of environmental regulation in the 1960s and 1970s, environmental law could have attacked the source of pollution through prevention instead of end-of-pipe control measures. It was not simply that environmental rules were not comprehensive and mandatory enough (although this is probably true, especially in Canada), but that their primary concern—environmental protection—was fundamentally limited. The primary need was not to protect the environment from our wasteful and toxic economy, but to stop our wasteful and toxic practices altogether.

For Barry Commoner (1990), the US regulatory model—the basis for environmental regulation throughout the capitalist world—has failed because it has avoided pollution prevention and fundamental technology change. His classic work, *Making Peace With the Plane*, systematically examined twenty years of US regulatory history (1970-90) to discover what worked and what didn't. He shows convincingly that what has worked is prevention—e.g. the banning of most applications of lead and asbestos; and what hasn't worked are painstaking efforts to monitor and control toxic substances and polluting technologies that shouldn't have been permitted in the first place. Commoner points out that the most damaging modern technologies have come from the petrochemical industry, and unlike the wondrous innovations of the electronics industry, synthetic petrochemical substances have been largely substitutes for more traditional, and less damaging, materials. To some critics of command-and-control, his solutions might seem like a de-emphasis of control in favour of increasing command. Perhaps this is true, but he does show that prevention is a low-cost strategy that typically requires much less bureaucracy than conventional regulation's monitoring and control of dangerous substances and processes.

William McDonough and Michael Braungart (2002) make a similar point in a different way, portraying the very need for regulation as resulting from design failure. They argue that, if products were properly designed to meet real needs, to regenerate natural systems, and to facilitate reuse, recycling and resource efficiency, etc., there would be no need to regulate them. Despite their rhetoric, it is probably fair to say that McDonough and Braungart are not criticizing all regulation, all economic rules, but the external command-and-control variety that fails to touch the producers' basic motivations and methods of making things. After all, ten years previously, Braungart (1994) developed the "Intelligent Product System" concept, a major regulatory proposal for extended producer responsibility (EPR) from a design perspective (see the *Horizons* section below). McDonough and Braungart's focus on "eco-effectiveness"—which sees a bigger picture than simple eco-efficiency—mirrors the role of prevention in Commoner's more systematic critique of regulation a decade earlier.

While the ideas of Commoner, McDonough and Braungart represent a radical critique of regulation, elements of the "design perspective" have found echoes in the general trajectory of regulation in the western countries. Notwithstanding Commoner's (justifiable) pessimism about existing regulatory regimes, we do find some movement—particularly in more progressive Europe—away from end-of-pipe controls and focus on point-source pollution. Beginning in the eighties, we find growing concern with firm eco-efficiency and pollution prevention—what some have called “middle-of-the-pipe” strategies. In the nineties, again particularly in Europe, there arose growing regulatory emphasis on consumption patterns—basically concerns of dematerialization. While so far as I know these efforts have not directly challenged economic growth, they nevertheless have exhibited some concern with disconnecting material from financial growth. These concerns about consumption involve not just private consumers, but “front-of-the-pipe” factors like product design and the application of the “precautionary principle” in dealing with toxic substances. Later in this chapter I will look at European Integrated Product Policy as an example of such a design orientation.

Postindustrial Trends in Regulation

Current European concerns with consumption patterns and product design are still minor and partial expressions of postindustrial potentials for dematerialization, prevention and political-economic integration. Fully unleashing these potentials requires a systemic change in regulation in line with these general observations:

- The state can no longer serve as the dual support for, and limiter of, accumulation. Its task is the ultimate elimination of accumulation and guiding a market transformation toward regeneration and qualitative development—through the creation of what Korten (1999) called “mindful markets.”
- Postindustrial regulation must *encourage/enforce higher standards*—in efficiency, service, and in social and environmental impacts. Moving with natural flows demands much more than simple environmental protection. Such a positive

project must be far more conscious and comprehensive than previous industrial regulation—as evidenced in new rules to implement extended producer responsibility (EPR). Even though it would be less deterministic and more flexible, planning would have to be ever more pervasive.

- The state cannot do it all alone. Partly because of the complexity of postindustrial economies, and partly because of the positive regenerative character of the production required, external control-oriented regulation cannot work. Social and environmental values must be embedded in everyday enterprise. For this reason, postindustrial regulation—even EPR—has to *go beyond the state*. It must not only affect but, in many cases, *be administered by civil society*. Current examples of non-state forms of self-regulation, grounded within industries and communities [which some academics now call "surrogate regulation" (Gunningham, Phillipson, & Grabosky, 1999)], include organic food, green energy, wood and building certification systems.
- This grounding of postindustrial regulation within civil society is one expression of a potential *transition from representative to direct democracy*—with the community, rather than the federal state, becoming the nexus of accountability. As discussed in *Designing the Green Economy*, this would involve new forms of political governance, including green municipalism, citizen assemblies, and network-based—as opposed to party-based—representation. This should parallel a growing incorporation of social and ecological values into market relations.

The self-regulatory character of an ecological economy would also have to be expressed by regulatory tools that go beyond law. They include some of the following, discussed in my first book regulatory tools:

- *the scale and spatial design* of both economies and production processes. Local and regional scale organically builds in certain kinds of accountability. The eco-industrial networks, discussed in chapter III, and the use of local natural and/or recycled materials, discussed in chapters IV and V, are examples of this.
- *monetary system design*, particularly that which mitigates the often destructive impact of monetary scarcity on everyday decision-making. This creation of scarcity has been a means of maintaining labour market discipline. But when people are forced to do anything for cash, communities and the environment usually suffer. As I showed in my book, community currencies can be employed that both alleviate or at least mitigate the compulsive power of money, allowing social and ecological values to influence the development process. Basic income schemes, and other ways of assuring that people's basic needs are covered, can do something similar. But community money systems, besides being more self-regulating, can also be employed to support local green market creation.
- *finance*, since control of investment money is a powerful influence on the direction of development. Green community financial networks—including development banks, credit unions, revolving loan funds, pension funds, etc.—can engage in preferential lending to green business. They are among the most important factors shaping the direction of the economy.

- *knowledge and information*—which is also a central theme of this dissertation, discussed in chapters II, VI and VIII. Information is obviously a key element of all design-oriented production (e.g. through LCA), but it can also be a regulatory force. Almost all civil-society-based forms of regulation discussed above are based in information that contributes to alternative forms of valuation. Such value is the core of green market creation strategy.

These are examples of regulatory tools for systems that counterpose design to external control. The economic rules must be rewritten. But such rules must work organically with everyday relationships that in themselves nurture regeneration. Law, scale, money, finance, knowledge, and more—all must work together to create appropriate forms of feedback, accountability, participation, decision-making, and support. No single solution—be it product stewardship systems, community currencies, tax shifting, local production, green procurement, etc.—is sufficient in itself to install qualitative value as the driving force of economic development. It bears repeating that such a design orientation is at once far more demanding and far more flexible than industrial command-and-control.

Integrated Product Policy

As noted above, the eco-design perspective is necessarily one of "regulatory pluralism" (Gunningham & Sinclair, 1997) that uses complementary approaches on different levels to foster environmental behaviour. An example of this kind of coordinated effort is the European Union's Integrated Product Policy (IPP). Although perhaps not (yet) a thoroughly radical eco-design initiative, it nevertheless applies a life-cycle approach through a number of measures on both the supply (product design) and demand (consumption) sides. As such it is an important step beyond both the prevailing "end of pipe" strategies (focused on cleaning up point-source pollution) and the "middle of pipe" initiatives (in cleaner production and pollution prevention). The consumption-side measures work with the ways customers choose, use and discard products, while also providing feedback to product designers and developers on the production side. There, at the "front of the pipe," IPP tackles product design factors that most determine ultimate environmental burdens (Charter et al., 2001). While it had its processors in national initiatives, IPP itself dates only from the late nineties; notably a 1998 Ernst and Young report, and a 2001 European Commission Green Paper.

Some of the areas it is trying to influence are managing wastes (e.g. take-back obligations); green product innovation (e.g. stimulating research and ecodesign); creating markets (e.g. public procurement); transmitting environmental information (e.g. eco-labelling, product declarations); and allocating responsibility (e.g. producer responsibility) (Charter et al., 2001; European Commission, 2004). It uses both voluntary and mandatory measures on both supply and demand sides. Table 6 summarizes many of the instruments in the IPP policy toolbox.

What makes IPP relatively unique in going beyond many existing national varieties of "environmental product policy" (EPP) is that it does not see itself as a stand-alone policy, but a framework to be integrated into existing EU economic and environmental policy. In addition, IPP is ambitious about the extent of its economic impact. According to Frieder Rubik (2001, p.225),

> The strategy of an Integrated Product Policy is to stimulate a total environmental market transformation; and is not restricted to some market niches.

> Environmentally efficient products sold in some niches might open the market, but the main point is to ‘green’ mass markets with large quantities of products sold and consumed.

Martin Charter (2001) suggests some elements of IPP in the following table:

Instrument	Including
Voluntary instruments	Voluntary agreements Self-commitments Industry awards
Voluntary information instruments	Eco-labels Product profiles Product declarations
Compulsory information instruments	Warning labels Information responsibility Reporting requirements
Economic instruments	Product taxes and charges Subsidies Deposit/refund schemes Financial responsibility
Regulatory instruments	Bans/phase-outs Product requirements Mandatory take-back

Table 6. Examples of Possible Instruments in the Integrated Product Policy Toolbox
Source: Charter et al, 2001

For this reason, it requires broad stakeholder participation. The 2001 EC Green Paper called for the creation of “product panels” comprised of producers, consumers and other stakeholders. According to the European Commission (2001),

> Such panels can be set up in various formats and need to be adapted to the issues considered. Such issues may concern the overall environmental performance of specific products or product groups but also specific issues for one or several product groups (e.g. the reduction of hazardous substances in particular products or product groups).

It is far too early to make too many definitive conclusions about IPP, especially since it is likely to improve over time. A number of criticisms have already been directed at it—particularly the fact that the EC Green Paper overly focuses on innovation at the product level at the expense of systemic change (Nuij, 2001). These criticisms are enlightening, but the weaknesses they target might be expected of a new initiative. They don't necessarily preclude growing concern with more larger systemic change, especially in response to EC policy.

Transforming Markets with EPR

If there is any single policy or regulatory realm in which the state can make its biggest contribution to creating closed-loop economic relationships, it is in Extended Producer Responsibility (EPR). While many other players can and should be involved in EPR, and while EPR itself is essentially a principle that can be implemented in many different ways, nevertheless the role of the state is very important to key forms of EPR.

According to Gary Davis (2002) of the University of Tennessee's Center for Clean Products and Clean Technologies,

> Extended Producer Responsibility is the principle that producers of products are responsible for the life-cycle environmental impacts of the whole product system, including upstream impacts inherent in the selection of materials for the products, impacts from the manufacturer's production process itself, and downstream impacts from the use and disposal of the products…Producers accept their responsibility when they design their products to minimize the life-cycle environmental impacts, and when they accept the physical or economic responsibility for the environmental impacts that cannot be eliminated by design.

EPR is a concept that was originally introduced to the Swedish Ministry of Environment in 1990 by progressive policy analysts and industrial ecologists associated with the International Institute for Industrial Environmental Economics (IIIEE) at Lund Sweden (Lindhqvist, 2000). The German Packaging Ordinance of 1991, leading to the "Dual System" and "green dot" label, was the most visible early expression of the EPR perspective, and focused on "take-back" requirements for packaging. It has had its difficulties, but it is responsible for substantial waste reduction in Germany and a recycling rate several times greater than North America for many kinds of packaging (Fishbein, 2000, p. 59-60; Geiser, 2001, p. 315). In Canada, modest EPR measures have been implemented to deal with tires, paints, batteries, and beverage containers—most on the provincial level.

It is important to understand that EPR, although commonly identified with take-back programmes, is a principle that can be applied in a variety of ways appropriate to the industry or situation in question. Figure 24 illustrates some of its variations:

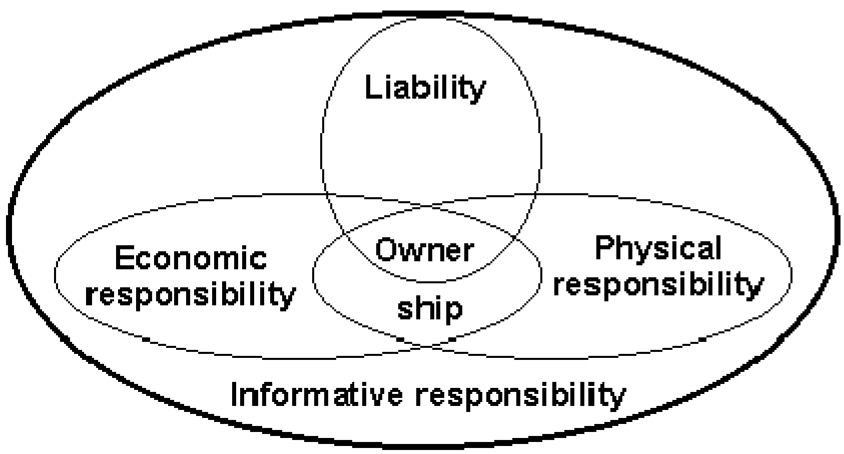


Figure 24. Varieties of EPR
Source: Lindhqvist, 2000

- ***liability*** where responsibility for environmental damages caused by a product—in production, use, or disposal—is borne by the producer;
- ***economic responsibility*** where a producer covers all or part of the costs for managing wastes at the end of a product's life (e.g. collection, processing, treatment or disposal);
- ***physical responsibility*** where the producer is involved in the physical management of the products, used products or the impacts of the products through development of technology or provision of services; one common expression of this would be…
- ***ownership*** where the producer retains ownership of the product over it entire service life, and

- ***informative responsibility*** where the producer is required to provide information on the product and its effects during various stages of its life cycle. (Thorpe and Kruszewska,1999; Lindhqvist,2000)

The underlying spirit of EPR is one of stewardship, and it is most clearly expressed in those sectors where producers retain actual ownership. The basic idea is that if producers are required to retain ownership (or equivalent responsibility) over products through their entire service lives, then the producers will become creative about conserving these materials and/or making them out of benign substances. Although the main concern is "post consumer" waste, this end phase is actually just the point of entry for measures that radically affect upstream extraction and production phases. When ownership remains centralized with manufacturers, instead of being distributed among consumers, the producers earn their profits not by churning out and selling as many products as possible, but by selling services. This might take the form of selling the use of a product (e.g. a TV or carpet), or the selling of an actual outcome (like pest control). EPR encourages both material conservation and a more direct focus on meeting needs. It is a means of disconnecting material growth from economic growth. It creates cyclical processes, builds full costs into market prices, increases resource-productivity, and facilitates service production all at the same time.

EPR can be applied in many different ways, and can be voluntary or mandatory. But its greatest potential can be realized when it is treated as the underlying principle of economic regulation. Then it can gradually transform the fundamental driving forces of the economy. Implemented comprehensively, it can be the single most important policy instrument in changing the River Economy into a Lake Economy. Questions of social democracy and environmental responsibility for the corporate order today are ultimately questions of accountability. Globalization is raising new concerns about corporate accountability that has generated new proposals for restrictions on corporate behaviour—like corporate charters and Tobin taxes. EPR is a positive and organic form of accountability which does not simply try to limit the destructive activities of business, but to "change the DNA" of the business enterprise. EPR presents as many opportunities for enterprise as limitations.

These positive opportunities are illustrated by the few legitimate examples of EPR that have been implemented voluntarily to date. The most well-known is the transformation of Xerox into a "document company" that sells copying services rather than equipment. This strategy allows Xerox to recycle or remanufacture 95 percent of its equipment (Fishbein, 2000, p. 82; Girshick, Shah, & Waage, 2002). In building products, the most-cited example is Interface Flooring which has experimented with carpeting service sales and leashing. The situations in both the electronics and carpeting industry lend themselves to this kind of stewardship. In electronics there are immediate paybacks, and in flooring, the corporate culture of the entire industry has generalized environmental measures like carpet take-back programmes. Other carpeting companies besides Interface, like Collins & Aikman and Shaw, are innovating in both recycling and healthy materials (Fishbein, 2000, p. 90-100). In other industries, particularly in North America there is much more resistance to the extended liability intrinsic to EPR. Nevertheless, the examples of EPR we find in industry today indicate that environmentalists and regulators can find allies within the corporate sector who can showcase the benefits and opportunities for enlightened producers.

Horizons for EPR: Intelligent Products and Product-Service Systems

EPR provides a model that can guide private firms, community developers and "surrogate regulators" (like eco-labelling programmes). But it is ultimately essential that economy-wide product stewardship be mandated by government, levelling the playing field for everyone. Perhaps the most well-known proposal for such a comprehensive system comes from Michael Braungart, a chemist who was formerly head of Greenpeace Germany's chemistry department, who is now working with eco-architect William McDonough in McDonough Braungart Design Chemistry (MBDC). In the early nineties, Braungart's Environmental Protection Encouragement Agency proposed a system which received widespread attention, particularly through Paul Hawken's *The Ecology of Commerce* (Hawken, 1993).

Braungart's "Intelligent Product System" (IPS) is based on the classification of products into three categories: Consumables, Products of Service (or durables), and Unmarketables. ***Consumables*** are products which are meant to be completely consumed in one use—like food or soap powder. They must be completely safe to be absorbed by the natural environment. ***Products of Service*** are things like TVs, cars and washing machines. The materials in these products might not be so benign in their environmental impacts, but they would be more tightly constrained in terms of disposal. Typically, they would be leased to the customer. At the end of their useful product life, they would be returned to the producer, where they would be dismantled and recycled back into production in some way. Producers would be responsible for this recycling, and so they would have great incentive to design their products for disassembly.

Braungart suggests another institution to reinforce patterns of recycling and disassembly: the "waste supermarket" which would be a centralized location where consumers could "de-shop" by returning used service products, including packaging. It would not be a dump site but a source separation depot.

Unmarketables are products and materials which cannot be consumed or used in any environmentally sound way. They might, for example, be toxic products like used lead-cadmium batteries. Braungart recommends that they be safely stored—at cost to their original producers—in state-owned "waste parking lots" in perpetuity—until such time as society found a way to safely dispose or use the products. This cost to producers would supply some pressure to create products which could either be recycled endlessly or, more likely, be made of more benign materials.

Braungart's system was proposed as the core of a new kind of regulatory framework which would also incorporate other kinds of performance standards and product or substance bans. While this amounts to a radical change from current forms of regulation, it seems quite unlikely that current economic and technological potentials for sustainability and eco-development can be attained without substantive reform of this kind. To date there have been no comprehensive initiatives to implement an IPS, but the regulatory trend, particularly in Europe, seems headed in this direction. As noted earlier, the focus of EU regulatory policy has begun to emphasize consumption patterns, along with a greater focus (through Integrated Product Policy [IPP] and Integrated Chain Management) on product design as a preventative strategy.

Another optimistic development is expanding research into what are being called "product-service systems" (or PSS). Researchers and policy-makers, mainly in Europe, are exploring the practical possibilities for "eco-service" production, which was first raised by Swiss industrial ecologist Walter Stahel in the eighties and early nineties. As described earlier, the service economy notion arises from a recognition that the real needs of consumers are mainly for services: clean clothes rather than detergents; mobility or access rather than cars; music, rather than CDs. The PSS perspective recognizes that to meet these needs, products and materials often have a role. (But as a means to satisfy the service-need, not as a goal of open-ended production). Many needs must be satisfied by some combination of a product and a service, and the product-service ratio can vary, in terms of either function fulfilment or economic value. A product-service system has been defined as "a marketable set of products and services capable of jointly fulfilling a user's need" (Goedkoop, te Riele, & Rommens, 1999). System organization commonly typically tries to facilitate

- sale of the use of product (rather than the product itself);
- operational leasing, rather than ownership by consumers
- repair rather than throwaway relationships

Almost by definition, a PSS involves many stakeholders, and usually requires their participation early in the design process. Because of its spirit of stewardship, it can entails major changes in property rights that radically affect the behaviour of both producers and consumers. This is quite obvious in the case of the leasing rather than the selling of durables. The implementation of PSSs involves changes for manufacturing companies (who must add a service component), for service companies (who add a product component), and for government (who have new means of realizing general sustainability goals and increasing the quality of life). Consumers, for their part, receive a greater diversity of choice, more direct meeting of their needs, and help in maintenance and recycling of products; but they also have some new stewardship responsibilities in keeping the cycle flowing. And, with greater participation in the design process, they also have great responsibility in examining the authenticity of their own needs, and distinguishing between "want" and "need".

In building, a service orientation would change of the focus of the industry towards upgrading and repair of existing spaces rather than the construction and sale of new buildings (Behrendt et al., 2003). However radical a development PSSs may seem, they are in many respects logical extensions of tendencies we already find in advanced production. According to Oksana Mont (Mont, 2002a, p.241),

> Product-service systems more appropriately respond to the demands of today than existing systems of mass production. This is an evolution of the economic transition away from standardised and mass production towards flexibility, mass-customisation and markets driven by quality and added value rather than cost. Core competencies, rather than physical assets, increasingly define leadership of companies on the market.

She also sees PSSs providing an additional environmental dimension to the ongoing transition from goods to service production in the advanced countries.

Substance Bans and Phaseouts

In chapter III, I summarized some important initiatives in the realm of toxics use reduction. A consideration here of design-oriented regulation requires special mention of a more radical tool: product and substance bans. Comprehensive EPR systems like the

Intelligent Product System, or any regulatory system based on the precautionary principle and pollution prevention, require a strong role for the state in banning inappropriate materials. While such bans may sound draconian, they are in fact a long-established practice in all industrial economies. In a green economy, however, the bans are based on ecological intelligence, principles of sustainability, and a longer-range view of human health. And while the state is the ultimate agent of these bans, they can also be implemented by assessment systems, professional associations and the like.

As discussed in Chapter I, industrial materials can be categorized into four basic areas: Degradable & Nontoxic, Persistent & Nontoxic, Degradable & Toxic, and Persistent, Bioaccumulative & Toxic (Geiser, 2001). Intelligent policy would have a different strategy for each area, with the overall goal of pushing industry increasingly toward as much production and use of Category 1 (degradable and nontoxic) benign materials as possible. As noted in Chapter III, the ecosystem-like integration of green manufacturing can make possible the production of a great diversity of products from small sets of benign materials. Category 4 materials—persistent, bioaccumulative and toxic—should be phased out as soon as possible because they inevitably create more problems than their use solves. While there are inevitable transition problems, science is rapidly multiplying the possible alternatives, and substitution strategies (discussed in Chapter III) offer a number of options for existing users of toxic substances.

As Commoner (1992) has demonstrated, many product bans could quickly pay for themselves several times over because of the pervasive human health and environmental impacts these materials have. Many dangerous substances often entail substantial regulatory to costs to monitor and control their use which could be eliminated entirely with their eventual phase-out.   The problem is that, at the moment, many internalized costs do not have a quick pay-back for the firms involved when their competitors, and whole international markets, benefit from de facto subsidies. Even when quick paybacks are possible, firms need knowledge and new arrangements to implement it. The model of Massachusetts Toxic Use Reduction Institute (see Chapter III) is instructive as to how government can contribute to a relatively painless transition to clean production. Transitional targets are essential, and a supportive information infrastructure to complement the stick of absolute standards. This is particularly true in the case of small enterprise, which lacks the resources for substantial change and is often not even aware of the regulations that govern their areas of business.

The State, Taxes and Subsidies

While the role of the state that is most crucial is its rule-making function, it has other powers that powerfully shape, and can potentially transform, markets. While certain corporate interests call passionately for the use of economic instruments like emissions trading to spearhead government sustainability initiatives, the state has long made use of economic instruments like subsidies and taxes—but in a tragically destructive way. For example, in Canada, tax rates for recycled material are on average 27 percent compared to 24 percent for virgin material, resulting in a $367 million disadvantage to the recycling industry (Gardner & Sampat, 1998, p. 31). This issue was raised in Chapter I *Bad Rules and Wrong Signals* when I discussed perverse subsidies and the use of the tax system to support extraction industry, suburban sprawl, fossil fuel use, and all manner of brown industry.

Positive subsidies can certainly be a useful tool in supporting conservation, renewable energy, eco-industrial development, benign and secondary materials industry, compact eco-development, etc. But many innovators, entrepreneurs and activists in these areas would be more than happy just to have perverse subsidies removed. This is because it would force polluters to internalize their costs, immediately levelling the playing field for green forms of production. In many countries, the environmental movement has spawned movements to eliminate perverse subsidies, like the "Green Scissors" campaign in the US, coordinated by Friends of the Earth.

Ecological Tax Reform (ETR) is an even bigger focus of activists and ecopreneurs. The most radical (i.e. fundamental) reform is known as ecological tax shifting, since it is designed to effect a major shift from taxing "goods" to taxing "bads"—in particular effecting a shift from resource-intensive to people-intensive production. Tax shifting is intended to be "revenue neutral" since the idea is not to increase the tax burden on the average person, but rather create incentives for producers to constantly improve (Friends of the Earth [FOE], 1998).

While a detailed discussion of green taxation is beyond the scope of this paper, it must be noted that tax shifting can and must play a central role in transforming building materials use. Every area discussed in this paper—from engineered wood, to carbohydrate-based plastics, to reused building materials, to design for disassembly, to natural building techniques, and more—can and must benefit from tax measures designed to internalize social and environmental costs, and jumpstart larger commercial markets for eco-production, eco-building and eco-materials.

Although comprehensive forms of green taxation that induce "shifting" are almost non-existent, environmental taxes are a common regulatory tool used to discourage pollution. A more modest form of shifting is present in green taxes that are earmarked for related complementary interests: for example a gas tax to support public transit, and landfill charges to support eco-industrial parks involved with secondary materials industry. Movement toward more substantive forms of taxation used to support green alternatives is continuing. New York State's recent implementation of tax credits for green building practices became a rallying point for the green building movement when the vinyl industry challenged PVC's categorization as an environmentally destructive material ineligible for tax credits. Despite substantial pressure, NY state did not back down, and the industry withdrew its court challenge (Greenbiz.com, 2003; Toloken, 2003).

Finally, green procurement, discussed at the end of the last chapter, must be mentioned again. This is not simply because of the absolute amount of state investment in the economy, but because of the strategic potential of government purchasing in supporting its green development and regulatory efforts in every sphere. Taxes on highly processed and polluting materials are made ever more palatable and effective, when combined with state purchasing of benign alternative materials.

This principle applies to all the economic instruments—and for that matter, all the policy tools in a government kitbag. All tools can be part of multi-dimensional strategy to change the economy's incentive structure and basic driving forces. Paul Hawken (1993), for example, urged the use of green taxation to support organizational initiatives like the Intelligent Product System. Other environmentalists have urged the use of green taxes to support other forms of extended producer responsibility. Taxation can be all the more effective a tool when combined with other kinds of initiatives to discourage the bad and encourage the good. Flexibility is essential in determining the precise combination of subsidy, taxation, etc. that have the optimal positive effect on specific markets. In some cases, subsidies for certain kinds of recycling can actually undercut savings gained through product redesign or reuse (Krozer & Doelman, 2003). Prices in different sectors are more or less elastic, or responsive, to tax measures, depending on specific market circumstances. Choices for taxes or subsidies or whatever should, again, be based on a clear overall vision and an integrated product policy that actually achieves the desired results.

A final comment must be made about the structural effects of tax shifting, a topic that is often raised concerning carbon taxes to deter global warming. That is, the fear that such pervasive change would be too shocking and damaging. The response is, assuming we want to survive, how conscious and controlled do we want the transition to be? Today we are probably seeing the beginning of long-term price increases not just in energy, but in the many products dependent on fossil fuel feedstocks. These price shocks are due to decreasing supply of oil, a trend that many argue is ushering in an era of continual oil wars, decline of suburban infrastructures, and demise of all oil-based industry. The building industry is very dependent on both oil-based materials like asphalt and plastics, and on energy-intensive materials like cement. Green taxes are a way to manage a transition to sustainable production that does not produce a negative shock, but a positive incentive for more sustaining and sustainable forms of production. As part of integrated state policy, and comprehensive industrial strategies, they can make the road much smoother not rougher.

Development By-Laws and Building Codes

Besides regulation that governs products, the use of building materials is also affected by the rules that guide development and construction.

As noted in Chapter I, this dissertation must eschew getting too deeply into urban design, since this is such a major topic in its own right. But here I cannot avoid at least a mention of the role of such large spatial design in materials efficiency. Suburban sprawl was, after all, a central (anti-)design element of the postwar Fordist Waste economy, providing "effective demand" for capitalist growth that had badly sagged in the decade before the war. North American suburbanization was what writer William James Kunstler (Greene, 2004; Kunstler, 1994) considers the greatest misallocation of material resources in human history. A recent study of Chicago and seven surrounding counties found that low-density development, as in the typical suburb, is around 2.5 times more materials-intensive per person than high-density development (Gardner & Sampat, 1998). Suburban development is incredibly expensive in real terms, but this has been hidden by a range of subsidies for infrastructure, roads, services and land—in addition to the most basic subsidy of all: cheap dirty energy. Today, as the era of cheap oil is drawing to a close, the potential for savings through densification is actually greater than the Chicago study suggests if communities employ an ecological brand of intensification—featuring green roofs, urban agriculture, edible landscaping, natural wastewater treatment, live/work communities, and reclaiming space from cars for people and plants. Such a project would entail a decisive break from conventional forms of zoning that overly segment commercial, residential, and industrial activities.

Building codes, for their part, are ostensibly a repository of society's accumulated wisdom on questions of health, safety and effectiveness of building practices. To some degree they actually are. But building codes in the developed countries have evolved in tandem with the trend in construction toward ever-higher levels of technology and the use of more highly-processed industrial materials. This has been a move away from many traditional low-impact materials and methods. As David Eisenberg (2002, p. 28) writes,

> Many of the worst examples of architecture and building are the short-lived, high-impact structures that today are being built all over the world out of code-approved materials and systems. Some of the oldest building materials and methods of construction can be seen in some of the most beautiful and enduring buildings in the world. Yet we have relegated indigenous, natural, low-tech materials and building systems to the status of 'alternative' materials and methods, even though in many climates, indigenous buildings are far more comfortable and less expensive than the modern buildings that have replaced them.

This has been possible because building codes ignore where materials come from, how efficiently they're used, and whether they can eventually be reused. Among other things, they ignore the impacts of extraction, manufacturing and disposal, as well as the level of embodied energy. Building codes as we know them now cover about a third of the world's buildings, and in these richer countries they have assured a higher level of safety and stability. But because they so foster resource-intensity they could not be applied to the rest of the world, since the planet does not possess enough resources. What's more, even in the developed countries, the role of building codes in protecting public health and safety has been undermined by the increasing use of synthetic substances that have spawned epidemic levels of chemical sensitivity and building sickness.

To really implement sustainable building, the codes should be grounded in life-cycle assessment (LCA) and encourage the use of regional natural materials. Many of these materials, described in Chapter V, exist in the public domain, and because of their very availability they have not spawned a powerful profit-making industry to lobby for their use. They fail to attract the kind of investment needed to pay for expensive research and testing. But recently, the insurance industry—which historically was a major catalyst for the development of building codes—has begun to pay closer attention to climate change and the role of the building industry in causing it (Berz, 2004). It has also become aware of the pervasiveness of building sickness, and its impact on both health system costs and worker productivity. Organizations like the Arizona-based Development Center for Appropriate Technology (DCAT) have begun to form alliances of regulators, realtors, inspectors, builders, and designers, to support research and testing of non-industrial low-impact materials, and also to carry on education with those parties on the total impacts of building codes. DCAT director David Eisenberg argues that, in the US, anyone can propose changes to the building codes and that the green building movement must be involved in building code transformation.

The State as Coordinator

Materials in a green economy must necessarily be subject to more comprehensive forms of regulation which can incorporate social and environmental concerns into the economy. This comprehensiveness often will mean higher performance standards enforced by law—as in the case of many forms of EPR. But it will also mean more flexible forms of regulation, including those implemented by non-state entities in civil society and emergent green industries. This flexibility is quite a different sort than most of that currently promoted by multinational corporations seeking less economic accountability. Stronger rules and more flexibility or participation are not in contradiction. Stronger rules that encompass deeper social and ecological values actually enable the state to be more of a guide and coordinator.

Regulation in an ecological economy is closely related to design, and design is intimately related to knowledge and information. The state can also play a vital role in guiding the research and coordinating the knowledge necessary for green development, whether this information is generated by the state, the universities, NGOs or particular industries. Indicator projects—from product life-cycle assessment, firm eco-accounting, eco-footprinting, national mass-balance accounts, to sustainable community indicators—ultimately must connect to government-supervised Green Plans and Community Development Plans. At a certain point, governments will have to consciously choose against policies geared to serve corporate globalization, export economies, resource-intensity, etc. But, because of the win/win nature of so many green economic initiatives, such either/or decisions may need not be made until ecological alternatives are well-established and an obvious choice.

Nevertheless even the most clearcut win/win propositions find stubborn resistance from what Lovins (1993) called the “institutional inefficiency” of organizations and individual trapped in what Roberts calls the “silo” mentality and organizational structures of large bureaucracies, be they public or private. Green development is what Roberts and

Brandum (1995) called “economics with peripheral vision,” which is able to see across boundaries, disciplines and industries to see multiple and overlapping benefits and efficiencies. Private companies are being challenged with new notions of the “stakeholder corporation” (Wheeler & Sillanpää, 1997), but governments must be even more responsible to understand the broad and complex constituencies and processes that are involved in green development.

CHAPTER VIII: CONCLUSION
BUILDING MATERIALS IN A POST-MATERIALIST TRANSITION

In a transition to an ecological economy, awareness about materials is perhaps more revolutionary than energy awareness because of how materials call attention to the use of energy and the *purpose* of economic activities. We seem to be, as discussed more thoroughly in *Designing the Green Economy*, in a historical transition from quantity to quality requiring a fundamental redefinition of wealth. This puts particular emphasis on questions of use and purpose, and such an emphasis is the essence of the ecological service economy. For our previous stage of economic development, which was focused on accumulation of money and matter, the linear "river" economy was somewhat appropriate. It certainly churned out a lot of stuff and continually revolutionized technology. Today, however, system limits make open-ended growth counterproductive; quantitative growth not only increasingly erodes quality but paradoxically begins to deepen, not alleviate, material scarcity. What's more, with industrialization having moved into the realm of culture, simply tapping the main productive potentials of our day depends upon a more explicit concern with human psychological, cultural and community development. Our survival depends on seeing materials as simply means to more qualitative ends, thus allowing their radical conservation and recycling. Thus a primary concern of this thesis has been to understand the role of building materials in an industry geared to service and regeneration.

As discussed in the opening chapter, building materials can play a transformative role not just because of the absolute volume and mass they represent, but how they are deployed to become our “built environment”—and so “distributed” in a fairly decentralized way everywhere we live and work. Changing the arrangement of their distribution affects the quality and efficiency of the entire economy. And because they have, compared to other products, such a long use phase in their life cycle, they influence development over a long time frame. In addition, next to food/nutrition, they are used to satisfy the most vital need we have—for shelter. For all these reasons and more, they can be a fulcrum to leverage change in the economy as a whole.

The distributed or decentralized nature of green (or postindustrial) development should be a starting point for strategy to dematerialize and detoxify the economy. As John Lyle pointed out, this has special historical significance: whereas industrialism effected a shift in the economy’s prime productivity from landscape to machinery, postindustrialism does the reverse. A green economy decentralizes production into the landscape, and its biggest challenge is finding the right patterns, through which the economy essentially flows in the winds of natural process. This of course puts special importance on the built-environment. It also influences how we look at work and labour, which must also be more embedded in the community and landscape—and more connected to previously invisible activities in the informal non-cash and semi-cash economy.

The point of this thesis has been, from an ecological design perspective, to synthesize possibilities for building materials in the key areas of production, consumption, recycling, evaluation and regulation. All too often these areas are considered separately in a reductionist way. It has been my conviction that a real design perspective entails seeing all these realms as essential (and complementary) arenas of transformation, even though each arena may entail very different change strategies.

This was a theme of my previous book, but this thesis provides an opportunity to examine design-based strategy more deeply in a particular area—that of building materials. Hopefully it can be thought-provoking for many of those in the building industry who deal with materials. But I also feel it might be of interest to those more generally concerned with either social change or 'information age' economic development strategy. I wanted to make some contribution to considering all the levels involved and the relationships between them—relationships which are all too often assumed or ignored in discussing sustainability strategies.

Knowledge and Value

This thesis features some fairly explicit concerns, having to do with the technological and organizational potentials for resource conservation, benign materials, recycling and reuse, green markets, community development, regulation, etc. But there are some other strategic sub-themes that pervade the entire work. One is the role of information, knowledge and education in the value revolution that is intrinsic to eco-economic transformation. It is no accident that I began, after the introduction, with a chapter on knowledge and value. It is value that ultimately drives the economy, and a postindustrial economy is driven by radically different values than industrial capitalism. These values are closely connected to social and environmental need, to potentials for human and eco-development, and our appropriate place in the cosmos. The information mobilized to support these values is therefore quite different, expressed in social and environmental indicators not money. The money economy has been based on various forms of invisibility—of both nature and human work—and contrary to much popular thinking, this invisibility cannot be rectified simply by turning nature and people into forms of money or capital.

So our knowledge must be more sophisticated and complex, seeing people and nature as much as possible in their own terms. This requires vast information about human needs and capacities, and natural systems. As noted earlier, in every sector, from agriculture to energy to manufacturing, eco-production is far more knowledge-intensive than its conventional industrial counterpart. The accumulative “river economy” has required far less knowledge than a closed-loop “lake” economy which must, in the words of Wes Jackson, “sponsor its own fertility” (Manning, 2004, p.38). Add to this the fact that, when we really focus on service rather than stuff, sectors like retailing take on major educational (as opposed to promotional) dimensions. This notion of retailing as a part of our educational system may sound strange, but it is simply one implication of establishing true a true knowledge-based economy. As Lester Brown once said, creating an ecological economy can be seen as a giant adult education project, and we can add that it is a project that also demands fundamental changes in the nature of existing educational systems.

Transforming Consumption

A second important sub-theme of this thesis has been the strategic role of consumption in transforming the use of materials. This, again, is because of the central role of end-use, need and purpose in an ecological economy. As Lovins said, real economic planning begins with need—with "hot showers and cold beer," not with production-for-production's-sake, no matter how 'ecological' it is.

This focus on consumption is, however, quite different than most mainstream preoccupations with consumption—which are often just variations on blaming-the-victim, and abrogating producer responsibility. My strategic focus on consumption is in no way in contradiction to Barry Commoner's insistence that the source of our problems lay in the design of production systems and producers' choice of technologies. Rather, it is a way of influencing those designs and choices by focusing first on real need, and the most sensible and efficient ways of meeting those needs.

Doing this, however, depends on transforming not just the content of consumption, but its form. So long as consumption stays an isolated individual activity, it will remain alienated and wasteful, and it will fail to touch designs of the production system. Sharing is an essential strategy for increasing the quality of life and the built environment, for major gains in conservation and efficiency, and for increasing community power, building democracy right into the economy. Movements to create the most dynamic green markets are cooperative ones, which depend upon and help build community. But these "consumer" struggles can and should also be struggles for green jobs, for local self-reliance, for extended producer responsibility, for holistic urban design, etc. They can be movements that help define the product-service systems (PSSs) that industrial ecologists see as the wave of the ecological future.

This kind of focus on consumption combines internal and external aspects of change. Looking at real need and quality helps us distinguish between "wants" and "needs" and also appreciate that many needs can be better fulfilled cooperatively and non-materially than through isolated commodity consumption. And as with natural building, we can become more aware not only that needed materials can be obtained much closer to home, but that many key forms of production can be carried on right at home. It is no accident that it is in the literature on natural building that we find the most emphasis on cultural change and voluntary simplicity.

As discussed in both of the last two chapters, the relationship between consumption and regulation in a green economy is particularly close—especially when mediated by knowledge. New forms of self-regulation can (and are) emerging in the building industry that make use of environmental information and the market power of allied consumers. These new modes affect and, in many cases, spring from new productive potentials within the building industry—like natural building and deconstruction services.

A strategic focus on consumption therefore can be a means not just of expressing social and environmental values (as in the case of most individual consumerism) but of transforming markets, the form and content of production, and the rules and driving forces of the economy.

Labour, Materials and Invisibility

One dimension that has not been prominent in this thesis, but cannot escape at least a mention here, is the role of labour. As touched on in chapter I, the industrial economy is defined by a particular relationship of resources to labour (essentially of nature to people). Sustainability can not really be attained without radically transforming this relationship. Green production is people-intensive and resource-saving, the very opposite of the industrial economy, and this has tremendous implications for the nature of work. I touched very briefly on the nature of work in service-based manufacturing, in deconstruction services, and in natural building. It tends to be innovative and higher-skilled.

The building trades, as craft unions, are relatively unique within the labour movement, strong in the more centralized sectors of a comparatively decentralized industry. Their basis of power—their trade skills, deriving from their preindustrial status as itinerant craftsmen—was the source of their conservatism and individualism during the Fordist period: the stereotype of the redneck hardhat. Today, in a postindustrial context, their independence and decentralization can make, and has made, it easier for many building tradespeople to establish alternative enterprises. (A mass production worker, by contrast, has to influence an entire industry to make substantial changes.) Building trade workers can more easily "become their own bosses" and free themselves from industrial cog-labour status. If they couple this freedom with a greater concern for what they're actually building, and greater attention to creating fulfillment in work itself, they take labour organization to a higher level of development.

The decentralization of green production—particularly in the built-environment—also raises another dimension concerning work. That is, the relationship to the informal and household economies. The industrial economy has always been a divided one, with invisible realms (including domestic work and the natural world) subsidizing the official-cash spheres. But the rise of the postwar mass consumption economy meant a particular explosion of various forms of domestic production that have been officially considered simply forms of passive consumption. Along with preventive health care, gardening and various forms of craft, self-help and "do-it-yourself" (DIY) building is a major part of our economy, albeit largely hidden.

A key task of green economic development is to make the invisible visible—and not necessarily by simply monetizing unpaid production. Feminist planner/historian Delores Hayden sees the greater integration of formal and informal spheres as happening via the "domestication of public space." That is, the nurturing values of the household begin to be applied to the outside economy, not the other way around. The question is where construction work fits in this domestication of the built-environment.

The importance of eco-infill development, building retrofit/renovation, natural building, green roofs, etc. means that many of the building trades, like the carpenters, must be ever more embedded in both community and landscape. The trades need to return to their origins in craft, but also be enriched by new social and ecological knowledge. They need to know more building science, but also more about materials and about the natural systems they try to fit within. The importance of eco-infrastructure to cities necessitates knowledge of natural wastewater treatment and hydrological cycles; of green roof construction; of edible landscaping, etc. The need to mine the waste stream makes builders, through deconstruction, into materials suppliers for themselves and secondary materials industry.

The green building crafts need therefore to be increasing integrated into community and environmental life. In fact, many building skills are already widely distributed in the population, as evidenced by size of the DIY building supply market. The growing popularity of natural building systems like strawbale and cob construction is further blurring the lines between formal and informal economies. Professional building tradespeople seem to have a future not simply as builders but as consultants to D-I-Yers in their communities, similar to urban permaculturalists and city farmers. Again, we have a central role of education and knowledge-networking.

While such possibilities have yet to influence building assessment systems like LEED, they have been implicitly recognized in some of the home greenup auditing programmes, many of which have been cognizant of the multiple benefits, social, environmental and economic (including job creation) of retrofit work.

Development Strategy

Ultimately people and governments must recognize that green development is a consistent and holistic body of development principles quite different from conventional industrial development. At some point, governments need to consciously apply these principles to create more self-reliant bioregional economies. But even before such change of mind by government, much can be done, since so many green alternatives can be implemented directly without prior control of the state. Not only this, but—as I discussed in chapters VI and VII—even new forms of civil society-based regulation can be implemented without control of the state. Rules changes implemented by the state are eventually necessary, but the primary task is establishing a spectrum of grassroots activities and enterprises, while distilling the practical values of ecological values through the spectrum of sustainability indicators. The next general task is a developmental vision, a general understanding of potentials, even if it cannot be a rigid blueprint. From the vision, coupled with an appreciation of the barriers to it, strategy emerges. And strategy is something all interested groups and sectors need. Again because ecological value must be embedded in all areas of society, movement strategy is primary, with state policy being derivative of strategy. Policy emerges from strategy, because enlightened government policy realizes that it can do very little in a vacuum.

Green change is, by definition, organic change. It needs to be qualitative, but it can only happen gradually and incrementally. Green economic development, as Robert Rodale (1985) used to argue, is like ecological plant succession. The key is to create green "pioneer enterprises" that can thrive in the barren economic landscape of industrial capitalism, and yet prepare the ground for enterprises that are increasingly ecological and democratic as the playing field becomes both more fertile and increasingly stacked against brown development.

The notion of organic change has also been echoed in many of the recent writings of industrial ecology. For some time, eco-industrial development was seen as essentially the creation of virtually ecotopian closed-loop industrial parks. Current thinking is stressing the need to begin with existing relationships among many stakeholders, and to simultaneously see the bigger relationships these exist within. According to the late Ed Cohen-Rosenthal (2003, p. 21),

> …we need to understand that eco-industrial connections occur all of the time in all kinds and sizes of businesses and communities. This occurs in advanced industrial companies …It also occurs at the traditional village commerce level in many developing countries where webs of relationships broaden capacity, redirect waste towards reuse and manage inventory, among other functions…In eco-industrial development, the issues of scale are central. Holonic solutions, which operate simultaneously at various scales, from the product to the workplace to the company to the region, provide different dimensions and call for different strategies.

In this sense, this evolved eco-industrial thinking parallels the ideas of architect Christopher Alexander (1979; 1987) who argues for every act of building to be seen as an ***act of repair*** of patterns that all people, buildings, businesses, and communities are already embedded within. The vision and principles, however, are crucial in making sure that incremental change *does* actually heal bad patterns, and not simply amount to adaptive co-optation that reinforces the status quo on another level.

In the building industry, I feel the greatest untapped potential for materials transformation begins with green market creation though various kinds of cooperative strategies using life-cycle information. My personal involvement in such an initiative, described in Chapter VI, convinced me that the very organization of information, coupled with community outreach through building retrofit programmes, is a powerful draw to the involvement of independent retailers of building materials. Having the retailers on side would seem to be an even easier task today because of the growth of Green Building Councils and building assessment systems like LEED. Governments, for their part, are significant players in LEED, with many public buildings, from municipal to federal level, now being certified. Information can indeed be power, if combined with other complimentary cooperative efforts like that of the community retrofit programmes, green power initiatives, municipal waste reduction efforts, building code reform, health and building sickness remediation, etc.

A crucial link for success is that between market initiatives and production. In Alameda County California, efforts to reduce the municipal waste stream have been linked with efforts to create eco-industrial parks to produce products from diverted waste materials (Mara, 2003). Green market creation initiatives need to be coupled with various initiatives in green manufacturing, waste management and green building. For example, local building assessment systems can be designed to specifically support regional waste diversion, green power, natural building, or even green job creation initiatives. Virtually every area has strategic hot-button issues, as for example, Toronto's municipal waste crisis. The latter is fertile ground for deconstruction as well as eco-industrial development initiatives.

For the economy as a whole, values and vision are again the starting point. Green development plans, coupled with indicator projects, are crucial to grounding green development in specific targets and criteria. Incubation centres for green enterprise development can be guided by those plans and indicators.

The plans and indicators also guide initiatives in green jobs training and education. At the moment, the educational system does a poor job in providing appropriate skills for regenerative economic development. The system is not generating the necessary solar collector and green roof installers, permaculture designers, deconstruction workers, industrial ecologists, etc. Universities can also be major contributors to the research necessary for knowledge-intensive eco-development and indicator systems (Milani, 2001). The state, from local to federal levels, can be involved with the range of tax, procurement, and subsidy initiatives described in Chapter VII, while it takes on more coordination of green development.

The primary intention of this thesis, however, is not to propose specific development plans, but to survey the range of aspects of materials transformation in building which are rarely considered together. Communities, builders, designers and regulators need to see for themselves where the opportunities and openings lay for regenerative “repair” of alienated patterns of production, consumption and use of building materials.

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