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# "Designing Healthy Houses and Cities: The Roles of Architects and Science."

Hal Levin
Building Ecology Research Group, Santa Cruz, California, 95060, and,
Lawrence Berkeley National Laboratory, Berkeley California 94720.
email: hlevin@cruzio.com

**ABSTRACT**
The meeting organizers have asked me to consider what must be done to integrate science and architecture to achieve healthy houses and healthy cities. "What," they have asked, "can be done in each discipline to advance the knowledge of each, to integrate the scientific knowledge into architectural practice, and to implement that knowledge to construct healthy houses and cities?" In short, we are discussing improving the pipeline from science to architecture in order to create ***sustainable*** communities. Clearly this discussion is important because our houses and cities today are simply not sustainable.

### *Healthy Buildings*

A "healthy building" was defined as one that is harmful neither to its occupants nor to the larger environment (Levin, 1995a). This, in fact, is an inadequate definition, focusing only on one requirement, that there be an absence of unhealthy conditions or influences. But beyond this absence there must also be a favorable environment, one that is functionally and aesthetically supportive of healthy lives. Functionally it must satisfy the basic needs of the occupants in a healthy and supportive way. Aesthetically it must be harmonious, peaceful, and pleasing.

In Japanese houses awareness of these requirements is reflected in the qualities of the tatami room, still an integral part even of most Japanese homes. It is a room that meets many of the requirements outlined above – functionally and aesthetically. The Japanese garden or even the typical small planter box in front of most homes also attest to the heightened Japanese awareness of the need for aesthetically pleasing homes and connection of the inanimate house with nature.

The health of houses and of the cities in which they exist are inextricable connected. The quality and healthfulness of the air, water, light and sound that enter a house as well as the general ambience of any house are dependent on the immediate surroundings. If air or water or sound or waste or radiation that leaves a house is unhealthy, it pollutes the city in which it exists. Therefore, neither the house nor the city can be healthy if the other is "unhealthy." A low energy-consuming, daylight-illuminated, naturally ventilated and thermally-conditioned building will still not be healthy if the air outside is polluted. And buildings cannot get discharge their pollution simply by emitting it into city air, water, and soil. This is not healthy or sustainable.

### *What is Sustainability?*

Sustainability literally means capable of being maintained and supported at a certain level. Sustainability is not only environmental but also social and economic. In general usage, and particularly in reference to economies, societies, and the environment, it is meant to suggest a human system in relationship to the environment that can continue indefinitely.

It is quite clear that the current social system including the economics and the impacts they have on the environment are not sustainable in the long run. While we do not know precisely what is required for a sustainable society, we do know it will be far more frugal in resource use and will release vastly less pollution into the air, water, and soil. It is also assumed by most authorities that it will be far less destructive of habitats and result in far lower rate of species extinctions than has been the case in recent decades. So how do architecture and science work today toward sustainable houses and cities? The subtext of this paper is to determine what can be changed to move more confidently toward sustainable communities?
Some people say Edo Tokyo may have been a sustainable city. But would 10 million citizens of Tokyo today want to live without the conveniences and comfort that they now enjoy?

Eco-villages in Finland have been reported to be less "sustainable" by Life Cycle Assessment than suburban housing. On average, eco-villages require more energy and raw materials, they produce more emissions, and they cost more than urban small-house areas." This conclusion takes into account the building of roads to reach the ex-urban environment as well as the resources (including energy) for transport to them (Harmaajärvi, 2000).

***Buildings' Impacts on the Environment***

Throughout the world, in developing and developed countries alike, buildings account for a significant fraction of all the resources consumed and pollution released.. Energy consumption and air pollution attributable to buildings account for more than 40% of national and global totals.. Water and material consumption are around 25 and 30% respectively. (Levin, 1995b).(See Table 1.) The magnitude of these impacts means that buildings present a large challenge and a large opportunity to improve the sustainability of our cities.

Table 1. Portion of total environmental burdens contributed by buildings (Levin et al, 1995)

| *RESOURCE USE* | *% OF TOTAL* | *POLLUTION EMISSION* | *% OF TOTAL* |
|---|---|---|---|
| Raw materials | 30 | Atmospheric emissions | 40 |
| Energy use | 42 | Water effluents | 20 |
| Water use | 25 | Solid waste | 25 |
| Land (in SMSAs) | 12 | Other releases | 13 |

The other major component of total human environmental burdens is transportation, especially in automobile-dependent societies like the United States, the Western European countries, and Japan. The study in Finland showed that homes in so-called "Eco-Villages" were actually more damaging to the environment than suburban houses due to the tremendous material and energy requirements for the infrastructure and fuels required to support housing distant from the city centers.

***Building Ecology***

In order to better understand the inter-relationships of buildings, their occupants, and the environment, we coined the term "Building Ecology" (Levin, 1981). Two decades have passed and we still see too little scientific study of these relationships nor integration of the awareness by architects and other professionals. More recently we have tried to emphasize the dynamic interdependence of buildings, their occupants, and the larger environment.

***Gap Between Science and Architecture***

There is a vast abyss between the knowledge and practices of scientists and those of architects. The practice of science is based on systematically accumulating evidence prior to conclusions and actions. In contrast, architects in practice act on what they know at the time the plans must be ready for construction. Traditional science proceeds cautiously and incrementally, slowly creating a body of knowledge that is constantly refined and expanded, each step forming the basis for the next. Modern architects have very little time to investigate the consequences of their actions and typically act on available knowledge within severe constraints of time and budget. They almost never study the results of their past designs which are each experiments of a sort.

Architects respond to the needs and demands of their clients, the requirements of codes and regulations, and to varying degrees, professional standards of practice. Science gets translated into compulsory codes, standards, and regulations as well as voluntary professional guidelines and handbooks. The process of translating scientific knowledge into compulsory requirements is often a matter of two decades or even longer. Leading professionals and consultants focus on emerging knowledge, but the majority of practitioners tend to repeat past practices out of an overabundance of caution and a lack of interest or mandate from their clients.

Science and architecture do have a basic driving force in common: borrowing a phrase from the late 19$^{th}$ and early 20$^{th}$ Century American architect, Louis Sullivan: "form follows funding." The practice of both science and architecture are heavily controlled by the economics that support their activities. Both are servants, most often in the service of industry and society. Occasionally they serve some higher, more elusive goal such as “truth” or “beauty.”

But now a crisis is upon us. Our buildings and cities are causing significant environmental harm by using unsustainable quantities of resources and emitting vast quantities of pollutants. Science must work to help architects design healthy houses and cities. To do this, we propose that certain scientific activities be accelerated and their adoption into architectural practice also be more rapid. A few examples are described below.

***Healthy Houses and Cities: Sustainability Targets***

There is presently no adequate basis for assessing the sustainability of alternative designs for houses or cities. This is due to the wide disparity in values and the paucity of data on the actual impacts of human activity on the future health of environmental systems. When alternatives are compared in terms of their scientifically defined impacts on the environment, great discrepancies are found in the estimates from different scientific articles. There are very inadequate data on the future social and economic impacts.

Table 2 Estimated external costs (US$/ton of air emissions)

| | | estimated external costs ($/t of air emissions) | | | |
|---|---|---|---|---|---|
| species | no. of studies | min | median | Mean | max |
| carbon monoxide (CO) | 2 | 1 | 520 | 520 | 1050 |
| nitrogen dioxide ($NO_x$) | 9 | 220 | 1060 | 2800 | 9500 |
| sulfur dioxide ($SO_2$) | 10 | 770 | 1800 | 2000 | 4700 |
| particulate matter ($PM_{10}$) | 12 | 950 | 2800 | 4300 | 16200 |
| volatile organic compounds (VOC) | 5 | 160 | 1400 | 1600 | 4400 |
| global warming potential (in $CO_2$ equiv) | 4 | 2 | 14 | 13 | 23 |

Efforts must commence to define sustainability from a scientific perspective. This involves identifying and quantifying targets for resource consumption and pollution emission in healthy houses and healthy cities. Clearly there are precedents (such as the work to define a Sustainable Netherlands and a handful of other projects) that can be drawn upon for guidance. Rapidly increasing use of concepts and methods of industrial ecology and life cycle assessment must be applied to the building sector. Scientists must refine the methods and develop the databases to allow architects, engineers, and planners to design and construct healthier houses and cities.

***Energy Conservation and Efficiency for Greenhouse Gas Emission Reduction***

Among the topics most pressing are the development of far more efficient buildings and building equipment as well as transportation systems to reduce radically the emissions of greenhouse gases associated with combustion-based energy production and use. Today we can produce buildings that use as little as 1/5 to 1/10 of the energy consumed in typical buildings. Science has contributed much to the development of technologies for more energy efficient building envelopes, lighting, space and water heating, cooling, and even food storage and preparation. Application of this knowledge lags behind, not due to science, but do to economics and habit.

***Durable, Non-Polluting Materials for Indoor Air Quality and Resource Conservation***

Scientists must develop and apply knowledge to produce building materials that will be long-lasting and will be low polluting throughout their life cycles. This might mean new composite materials made from natural or renewable resources or from minerals -- but in forms that can be re-used over and over, such stone or ceramics. These materials would be low polluting in their production and use phases and would not require toxic materials for surface cleaning or refinishing.

## *Energy Production and Consumption*

The health of cities relates to their economic bases. A major environmental determinant is the quality of water and air. Transportation and energy production systems are the two major sectors dominating energy use and determining air quality. Water quality can be addressed, but availability is a barrier to healthy cities in many parts of the world today.

### *Design Tools to Enable Environmentally Preferred Solutions*

For architects to be more open to integrating scientific information, the implications of science need to be translated into codes or guideline language as well as handy algorithms that make sense within the practice. For instance, if life cycle assessment tools are to determine environmental impacts of alternative design solutions, the information must be available without much or even any data entry that beyond the normal design process. If CADD software operation contained background programs running LCA tools, designers would be more likely to use them. Then they could continually be informed of the environmental implications of each decision or compare alternative solutions. Such programs are now under development.

### *Indoor Air Quality*

While substantial progress has been made, there are still gaps between the tools and methods of science and those that are available to designers. Issues include translation of scientific VOC emissions testing into practical tests that manufacturers and architects find affordable and reliable. Assessment of mold and moisture problems are heavily dependent on determination of "water activity" at surfaces, yet no measurements are available for this parameter. In Japan, perhaps, the problem of mold and moisture has not been adequately addressed, and condensation in building envelopes may be a major factor.

### *Summary and Conclusion*

The gap between science and architecture must be bridged to achieve healthy houses and cities. Unless this process occurs quickly, irreversible environmental damage may result in significant barriers to creating sustainable buildings. While some progress has been made, but enormous challenges remain.

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