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Beyond the Limits of Sustainable Architecture

A New Material Sensibility for the Twenty-first Century

Jenseits der Grenzen nachhaltiger Architektur

Eine neue Materialsensibilität für das 21. Jahrhundert

Dokument in Englisch

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During the last decade of the twentieth century the high-rise building trades were booming. The traditional leaders in skyscraper construction, the urban centers of Europe and North America, were erecting tall building after tall building, reshaping the cityscape in typically energetic fashion. But the real boom was happening elsewhere. In Asia, nearly 1,800 skyscrapers were constructed during the 1990s, making the region the busiest builder of large-scale structures in the world. In Shanghai alone, where in 1969 there were only a dozen high-rises, 138 steel-and-concrete towers transformed the skyline in a single decade.1

One might applaud these stunning feats of engineering. The recent building boom in East Asia transformed hundreds of thousands of tons of raw steel into dozens of potent symbols of technology, prosperity, and progress. They celebrated the dynamism – short-lived it turned out – of a late-twentieth-century economic force, the so-called Asian tigers. Yet these new skyscrapers also symbolize many of the environmental problems that have come to define contemporary building design. And they are only a fraction of massive stock of large-scale buildings that grows daily in industrialized nations and at an ever-quickening pace in the developing world.

So what’s the problem with large-scale architecture? It’s not just that buildings have gotten so big – it’s more complex than that. We are quite capable of designing big, majestic, and inspiring buildings that celebrate human creativity and pleasure with enthusiasm and environmental sensitivity. Nevertheless, on a global scale, the physical impact of increasing building mass is undeniable. As we move into the second century of the skyscraper, the construction of buildings is consuming some three billion tons of raw materials each year. By most estimates, new construction accounts for 40 percent of the world’s raw stone, gravel, and sand used each year; 40 percent of the processed materials, such as steel; and one-quarter of its wood harvest. Together, new and existing buildings account for two-fifths of the world’s annual energy use, one-sixth of its water consumption, and one-half of its waste stream. In fact, the construction and maintenance of modern buildings rivals the material and energy use of the entire manufacturing sector of the global economy.2

This gargantuan appetite for raw materials results in some of the same problems associated with the production and consumption of consumer goods. Office towers, like industrial processes, are powered by fossil fuels and nuclear reactors. Their wastes pile up in landfills and pollute the air, water, and soil. Through material supply chains that span the world, the impact of buildings extends well beyond their local footprint. An architect’s choice of materials in Manhattan, for example, triggers a series of events halfway around the globe in Madagascar or Brazil. Depending on the material – it might be raw gravel for cheap concrete, a rare, precious cabinet wood, or iron ore for steel beams – an architect’s uninformed choices might contribute in some small way to deforestation, an increase in toxic mine tailings, or the loss of biological and cultural diversity. A preponderance of uninformed choices has led to the slow unraveling of the web of life.

An architect’s material choices also influence human health. Beyond the widespread environmental problems that undermine social well-being, the various ingredients that add up to a building also have invisible, long-term effects on both building occupants and those who manufacture and dispose of architectural materials. Indeed, none of the materials used to make large-scale buildings is specifically designed to be healthful for people. Even a cursory inventory begins to suggest some of the challenges architects are dealing with.

Consider, for example, the ubiquitous use of polyvinyl chloride. Polyvinyl chloride, better known as PVC or vinyl, is a common ingredient in windows, doors, flooring, wall-coverings, interior surfaces, and insulating materials. Many formulations of PVC have been known to contain toxic heavy metals and plasticizers that are carcinogenic and endocrine disrupting. Equally common is formaldehyde – a reproductive toxin found in particleboard, paints, and textiles – and other volatile organic compounds (VOCs), some of which are suspected carcinogens and immune-system disrupters that occur in adhesives and carpets. Formaldehyde and VOCs seep, or off-gas, from architectural materials, accumulating in tightly sealed buildings in concentrations that make indoor air quality on average three times worse than the most noxious urban air. Design flaws that trap moisture in buildings add mold to the list of substances fouling indoor air. This forced flow of chemicals and molds through inadequate ventilation systems adds up to the costly health problems associated with Sick Building syndrome, which affects more than 30 percent of new and renovated buildings worldwide. Energy-efficient buildings, which are designed to require less heating and cooling, and thus less air circulation, only make things worse. Fortunately, an expanding palette of materials is allowing designers to phase out the use of PVC and other toxic substances, a very promising step for twenty-first century architecture.

The Building as Machine

Many of these problems with building mass and materials can be traced to aesthetics. “The house is a machine for living in,” Le Corbusier famously said.3 Writing and working in the early and mid-twentieth century, Le Corbusier and the other modernists such as Walter Gropius and Mies van der Rohe pursued a rational, minimalist approach to architecture to free it from class distinctions and the nationalist ideologies of the day. They employed modern materials, new technology, and industrial forms – the building as a sleek, mass-produced machine – in the interest of replacing unsanitary, inequitable housing with clean, austere buildings for the masses. Their theories and their glass-walled high-rises helped articulate a modernist sensibility that came to be known as the International style. These architects, and those who followed them, designed monuments to rational form and pure function, which to a great degree achieved their end: an international aesthetic largely freed from the constraints and ideologies of particular places.

Out of the aesthetic drive of modernism emerged a new material sensibility and a novel concept of building mass. Modernist architects conceived of buildings as light, rectilinear enclosures of dynamic volumes of space. The robust mass of traditional stone and brick provided a poor representation of this modern idea of form. Instead, the modern architect turned to concrete, steel, and glass, far better materials for suggesting lightness, space, transparency, and sleek, industrial modernity.

In his early career, Le Corbusier was especially drawn to glass. As Reyner Banham writes, “all other materials seem to have been in his eyes poor substitutes for glass, his ideal of the de-materialised building skin. . . .”4 Yet Le Corbusier and others after him were to find glass walls a mixed blessing. Consider his Cite de Refuge: When the Salvation Army hostel opened in December of 1933, the building’s south-facing, multistory, sealed glass wall offered, as Le Corbusier wrote, “the ineffable joys” of sunlight and warmth on a cold winter day.5 When summer rolled around, however, the ineffable sunlight made the tightly sealed Cite de Refuge an unbearable hothouse, a problem that could only be addressed with another emerging technology of the day, air-conditioning.

Called “man-made weather” by its inventor, Willis Carrier, air-conditioning liberated modern architecture from nature.6 It allowed Le Corbusier to dream of “one single building for all nations and climates,” the machinelike structure independent of place.7 With a few notable exceptions, his dream has come true. If we scan the skyline of Shanghai we see little that is much different from the skylines of Los Angeles, Manhattan or Frankfurt.

The buildings are steel-and-glass boxes, tightly sealed, short on fresh air and natural light, their internal ecosystems divorced from their surroundings. If buildings such as these were to be a stroke against nationalism, they have become as well a leveler of cultural diversity, overshadowing the very rich differences between Eastern and Western approaches to shelter and landscape.

Tracing the influences of modernism, we can begin to see how architectural form influences culture, and how material sensibilities and design issues raise serious cultural questions. And this is where today’s architects might want to be careful and humble. Developing new designs in response to cultural issues is not always a very clear process. The mid-twentieth-century modernists were very aware that they were involved in a cultural struggle, yet this did not necessarily help them achieve positive cultural ends. In 1950s Berlin, for example, architecture was a key signifier of political identity. East German communists thought modernism was decadent and useless – the skyscraper was seen as a cathedral of capitalism – while the modernists believed their work symbolized an enlightened, egalitarian alternative to Stalinism. Ironically, no skyscrapers were built in West Berlin during the Cold War, while in East Berlin mammoth TV towers became the tallest structures in Europe. Nonetheless, as James Howard Kunstler writes, Stalin’s hatred of modernist buildings actually empowered modernism in the West, where it became “the architecture disliked by fascists and communists, and therefore the official architecture of democracy and human decency.”8

But human dignity was not aided by modernism in either East or West Berlin. “Perversely,” Kunstler continues, “postwar West Berlin, the island of liberty in a sea of socialist oppression, became a showcase of monumental Bauhaus-inspired modernism composed of intrinsically despotic buildings that made people feel placeless, powerless, insignificant, and less than human.”9

Not what one would hope for from the architecture of human decency. Unfortunately, the landscape of West Berlin – a landscape of machines for living designed for all nations and climates, but not specifically for West Berlin – is being repeated with great regularity around the world, undermining not only the health of the land, soil, air, and water, but the very real human need to take pleasure in the designs and materials of the built environment and the natural world. We can do far better.

Dematerialization: A New Take on an Old Perspective

A new generation of architects has set its mind on just that. After years of brutish resource-extraction and energy use, designers of large-scale buildings are becoming aware of a new sensibility that links architecture to environmental concerns. Many are trying to address the negative effects of buildings with designs and practices that use energy and materials more efficiently.

This shift among architects has emerged in the context of a wider movement toward resource efficiency associated with a desire for sustainable development. Sustainability is a slippery and not very descriptive term, but it is often used to describe efforts to integrate social and environmental concerns with the more carnivorous aspects of the global economy, making commerce more viable over the long-term. One of its goals is the decoupling of material use from economic growth, which is essentially a strategy of doing more with less in an increasingly crowded world. A report by the World Resources Institute, for example, projects a 300 percent rise in energy and material use as world population and economic activity increase over the next 50 years. As long as economic growth implies an increase in material use, the study warns, “there is little hope of limiting the impacts of human activity on the natural environment.” But, the report continues, if industry can become more efficient, using less material to provide the goods and services people want, economic growth can be sustained – thus decoupled from resource-extraction and environmental harm.10

This perspective, translated into practice, is often called eco-efficiency, which became a leading business strategy in the 1990s and influenced architecture as well. Eco-efficient businesses try to release less waste into the air, send less material to the landfill, and make fewer dangerous chemicals. “Reduce, reuse, recycle” is eco-efficiency’s popular mantra. Architects influenced by eco-efficiency follow a similar path. Many try to do more with less by reducing the energy consumption of buildings.

Designers of eco-efficient buildings employ a variety of tools to minimize energy use. Typically, big energy-savers are heavily insulated and tightly sealed to minimize heat and cooling loss and to reduce the need for air-filtration. Dark tinted glass, or coated “superwindows” that emit light but reflect heat, diminish the building’s demand on its air-conditioning system and thereby cut fossil-fuel consumption. The local power plant, in turn, releases a smaller amount of pollutants into the environment, cutting emissions of particulate matter and greenhouse gasses.

Formal innovations are sometimes combined with new materials to make big buildings more resource-efficient. Edificio Malecon, a 125,000-square-foot office building in Buenos Aires, for example, was designed to minimize the heat of the sun by pinching its long, narrow mass on the east and west ends and using sunshades to screen its broad northern and southern exposures. Together, these innovations are said to “virtually eliminate direct solar radiation during peak cooling months.”11

Recycling building materials and retrofitting building mass are also being employed to reduce the environmental impact of large-scale structures. The renovation of the Audubon Society’s offices in a 100-year-old building in Manhattan preserved 300 tons of steel, 9,000 tons of masonry, and 560 tons of concrete while making the building a model of high-tech energy efficiency.12 Projects such as this suggest both the typically unseen potential of the current building stock and the need to construct new buildings for multiple uses in the future. As an emerging market for recycled glass, sheetrock, and carpeting, as well as for reusable high-quality construction materials, grows more stable, buildings and materials with many lives may become more the rule than the exception.

Other approaches take direct aim at reducing resource-consumption by simply using less material to make things. Dematerialization, as this strategy is often called, is the materialist's way to efficiency. One of its leading proponents is Adriaan Beukers, professor of composite materials and structures at Delft University of Technology. Beukers, a former rocket-materials scientist, is intrigued by lightweight structures and the possibilities of getting maximum performance from minimum materials. His premise is simple: lightweight, fiber-reinforced composite materials, intelligently composed, can yield structural strength while dramatically cutting resource-consumption.

Beuker's "minimum energy structures" are inspired by the tools and shelters carried by ancient nomadic people, which had to be light for easy transport. They were made of natural polymers, such as bone or skin, or composites such as straw and mud. Fast forward to the twenty-first century: With energy resources in decline, Beukers says, we have to remember how to travel and build light. Today's synthetic composites – layered textiles woven with carbon fibers and resin, for example – give us the technology to do so. Composite materials are already being applied to new products, such as windmill rotor blades and a lightweight beer keg that deflates after use, saving transportation costs and valuable steel.13

Beukers thinks this is the future of architectural materials, too. He sees inflatable buildings made of strong, flexible composites; textiles molded into prefab materials; Bucky Fuller – style structures relying on the relation between tension and compression; and, harking back to ancient design, structures based on the tensile strength of tents.

We already see "tensegrity" applied to our domed stadiums, and architects such as Renzo Piano often use tentlike roofing. Some believe "a culture of 'lightness' is beginning to take root," seeing in its emerging influence a "key to apprehending the relationship between design and sustainability."14

Do these approaches to sustainability – efficiency, recycling, dematerialization, lightness – signal the decoupling of materials from economic growth that the World Resources Institute is hoping for? Perhaps. Can we begin to feel more sanguine about architecture's effect on nature and human culture? Well, maybe not.

Each of these strategies has something to offer. Certainly, retrofitting an old building and reusing materials is a positive way to create new, pleasant spaces for office workers. And it's true that efficiently constructed buildings cut waste, and that light materials minimize resource-consumption. But the overall design and material makeup of efficient buildings is very much like the skyscrapers of Shanghai and Berlin. While their designers may make material substitutions – superglass, triple glazing, recycled plastic surfaces – the chemistry of materials in efficient buildings tends to be largely the same as that in both their predecessors and their more gluttonous contemporaries. The same carcinogens, the same toxic heavy metals, the same endocrine disrupters – only now more tightly enclosed. Are these the kind of buildings we want all over the world?

Recycling, too, can be problematic. Most recycling is actually downcycling, with materials losing value as they circulate through industrial systems. When various plastics are recycled into countertops, for example, valuable materials are mixed and can't be recycled again; their trip to the landfill has only been slowed down. The same is true of Beukers' ultralight composite materials; they are hybrids right from the start and can't be effectively recycled even once.

That may not sound terribly troubling in these times, but mixing construction materials not designed to be recycled can be quite destructive. The strength of steel, for instance, is compromised when it is mixed with other metals in the recycling process. Nevertheless, low-grade steel made from recycled American automobiles is often used for construction overseas.

Its wide use in Turkey may have been responsible for the collapse of so many buildings during the earthquake that rocked the country in 1999. Recycled steel from the U.S. and Europe is also used for building construction in Asia.

Mixing metals also dilutes the value and increases the impact of materials. When rare and valuable metals such as copper, nickel, and manganese are blended in the recycling process their discrete value is lost forever. Creating new stockpiles is extraordinarily costly. Mining and processing one ton of copper, for example, creates 600 tons of industrial waste.

A materials passport, much like the bar code on consumer goods, could change that. The passport would essentially guide materials through industrial cycles, routing them from production through reuse, defining optimum uses and intelligent practices. Valuable copper would remain available for use as valuable copper, not just one of many ingredients in hybrid products of lesser value. New recycling processes can even add value to materials as they flow through the cycles of industry.

At issue in today's practice of sustainable architecture is not the good intentions of all those trying to make a difference by doing things efficiently. It is simply that efficiency as a goal, as an end in itself, does not address the fundamental flaws in building design. Sometimes it makes things worse. Efficiency falls short, not because it does not cut or limit or minimize enough, but because it is utterly defined by limitations: seeking to be merely sustainable, one arrives at a minimum condition for survival – not a very inspiring prospect. Souped-up sustainability is still a kind of spare minimalism, a way of trying to be less bad.

A New Relation to Materials

Imagine a factory or office building that celebrates the abundance of nature's material wealth, rather than bemoaning its shortage. By clearly understanding the chemistry of natural processes and their interactions with human purpose, not only can we imagine such places, we can build them. This suggests a radical shift from designing large-scale buildings as inanimate, one-size-fits all objects into which we plug power and largely toxic materials, to buildings designed as life-support systems embedded in the material and energy flows of particular places. It's a design strategy animated by ecological intelligence.

Ecologically intelligent design seeks not efficiency but effectiveness and rematerialization. Rematerialization can be understood as both a metaphor and a process. In the industrial world, it refers to chemical recycling that adds value to materials, allowing them to be used again and again in high-quality products. The process is modeled on nature's nutrient and energy systems, which perpetually recycle materials in closed-loop cycles. Industrial ecology applies the structure of these natural systems to the management of industry's material flows, so that all products and materials, after their useful commercial lives, can be returned to the soil or circulated in industry forever.

Applied to architecture, rematerialization describes both a relationship to materials informed by natural systems and a layered strategy for redesigning the chemistry of large-scale buildings. The key to effective re-materialization – and to ecologically intelligent architecture – is not limiting mass or reducing energy-consumption, but designing healthful materials that can safely circulate in closed-loop cycles and integrating nature's own nutrient and energy systems into building design. The goal is not less impact, but more – life-supporting structures that leave a big, positive ecological footprint: more habitat, more clean water, more fresh air, more pleasure, more beauty, more biological and cultural diversity, more fun.

Ecological intelligence begins with material chemistry. We are only beginning to understand the effects of the chemicals we live with every day in our homes and workplaces, and each year, approximately 2,000 new chemicals are introduced worldwide without any need for approval. The toxicological data simply can't keep up. Through existing chemical assessments, however, we do know enough to begin to select materials for architecture that are safe, and even beneficial, for human and environmental health.

Consider insulation. It's not the most visible or exciting material on the block but it's crucial to both health and performance in large- and small-scale buildings. The typical palette includes insulation made from fiberglass, rigid foam, cellulose, or polyurethane – all of which contain problematic substances. The resins in batt insulation contain formaldehyde; rigid foam contains organohalogens, which are toxic, or styrene, a carcinogen; cellulose contains reproductive toxins, and so on. But there are alternatives. Rice-husk insulation and rice straw, for example, are achieving market viability: they are safe, effective, inexpensive, totally biodegradable, and produced with a renewable resource that does not displace a food crop.

As harvesting rice husks suggests, the various effects of materials extend from the molecule to the region, from a particular building and its inhabitants to the human settlements and natural systems in which they are embedded. Materials harvested intelligently tend to preserve rather than damage the economic, environmental, and social assets of communities near and far. Wood products certified by the Forest Stewardship Council, for example, must be harvested following well-defined principles, which protect biological diversity, honor the rights and knowledge of indigenous people, and respect the need to carefully manage working forests. The principles, in essence, aim to enhance a wide spectrum of community wealth, and they begin to suggest the ecosystem perspective that underlies ecologically intelligent design.

With an ecological perspective, a material life cycle begins to emerge. Typically, the life cycle of a product is a one-way trip to the landfill or incinerator. But when a product has a safe, positively defined material chemistry, it can flow in a closed-loop cradle-to- cradle life cycle, providing nourishment for nature or infinitely recyclable materials for industry. Just as in nature, when the by-products of one organism become food for another, the flow of these biological nutrients and technical nutrients in their respective cycles eliminates the concept of waste.

We don't have to settle for imagining cradle-to-cradle architectural materials; they already exist. An upholstery fabric I designed with Bill McDonough as a biological nutrient abrades safe fibers rather than off-gassing toxicity and will decompose after its useful life. A commercial carpet company, BASF, has developed a system to retrieve old nylon carpet fiber and transform it into its highest quality yarn without any significant loss of material. The process adds value to the old nylon rather than downcycling it into a product of lower quality. That's rematerialization, not dematerialization. Or reincarnation – a material coming back into existence at a higher level of evolution.

Life cycle thinking becomes truly effective within the conceptual framework of intelligent building systems, such as those being developed by the architectural researchers Volker Hartkopf and Vivian Loftness of Carnegie Mellon University in Pittsburgh. Hartkopf founded the Center for Building Performance and Diagnostics, where he has developed a consortium of 42 building-industry partners conducting research on new construction technologies, from raised-access floor systems to skylights for daylighting, recyclable carpets to sustainable seating. Perhaps as important as the actual technical advances is the emerging framework for cooperation between industry leaders, researchers, and architects. Hartkopf's success at advancing research within partner companies suggests the real possibility of establishing cooperative systems for the industry-wide tracking, retrieval and re-utilization of architectural materials.

Together, Hartkopf and Loftness conceived the idea for the Robert L. Preger Intelligent Workplace, a model of smart systems applied to passive strategies of climate control in office buildings. Previous research had led them to conclude, Hartkopf told Architecture magazine, that conventional office buildings were inadequate “if they were measured through the eyes, noses, and ears of the occupants.”15 Seeking an alternative, the Intelligent Workplace is designed to use technology to create a high level of personal health and comfort. A system of intelligent indoor-outdoor sensors monitors temperature, air quality, wind speed, and humidity, making the building incredibly responsive to its environment. A central computer system tapped into the sensors lights the building as needed and optimizes flows of fresh air, daylight, shading, and radiant heat, which handles most of the climate-control load. This marriage of high- and low-tech effectively enmeshes the building in local energy flows, tapping into the surroundings to the advantage of all its inhabitants. Intelligent indeed.

Ultimately, that is what guides ecologically intelligent design – the openness and attention to a place that allows one to discover fitting materials, fitting forms, fitting systems, so that human habitation supports the life of a locale. Combining this local knowledge with an understanding of intelligent materials and energy systems, architects can create buildings that encourage healthy interactions between the natural environment and human settlements.

The Adam Joseph Lewis Center for Environmental Studies at Oberlin College, designed by William McDonough + Partners, is such a building. In fact, the Lewis Center fits in its surroundings like a tree in the forest: Enmeshed in local energy flows, it accrues solar energy, makes oxygen, filters water, and creates healthy habitat for living things. Geothermal wells heat and cool the building. A constructed marsh-like ecosystem breaks down and digests organic material and releases clean water. The fabrics used for upholstery are biological nutrients and the carpeting will be recovered and recycled when it wears out. The surrounding landscape provides social gathering spaces, instructional gardens, and a newly planted forest grove, which is re-establishing the habitat of the building’s northern Ohio location. Inside and out, the Lewis Center is becoming entwined with its place, teaching day to day how to mindfully engage the world.

There is still a long way to go. Architecture has just begun, really, to assess its materials, determine their problems, assets, and positive effects, and design new ecologically intelligent materials that flow in cradle-to-cradle cycles. Perhaps there will come a day when all building materials have passports that enable architects and builders to quickly assess their material chemistry and life-cycle potential. That would make a process that is today quite arduous a pleasurable investigation into the history and future of a material: Where has it come from? How was it harvested? How did it get here? Where is it bound at the end of its life? All those questions will add up, as they do today, to a very rich story about the many ways in which we shape our world. I can’t imagine not wanting to know that, nor wanting less material to wonder about.

Why not create buildings and systems that give more people more of what they want, need, and love? Cradle-to-cradle materials allow us to do so. And intelligent buildings allow us to leave an ever-larger ecological footprint, an imprint on the world that we can delight in rather than lament. Ultimately, it will be the delight buildings inspire, the way they enhance our feeling for life, that will move ecologically intelligent design from the agenda of a few to the demand of many. Imagine buildings so delightful, so expressive of the world’s diverse interactions between nature and human culture, so comfortably affordable for so many, so able to inspire wonder in the living world, that the demand for them is driven by pleasure from the bottom up. Then perhaps, the newest skyscraper in Shanghai will be powered locally and remotely by the wind and the sun, and on a stroll down a wide, sunlit hallway you will feel a breeze from the East China Sea and know quite certainly just where you are and how it feels to inhabit that unique coastal land.

Notes

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