D. Design for Materials Recovery

> When you build a thing you cannot merely build that thing in isolation, but must also repair the world about it, and within it, and the thing which you make takes its place in the web of nature.
>
> —*Christopher Alexander*

Designing for the recycling and reuse of buildings and their materials acknowledges the life cycle of a building from material sourcing (resource extraction) through materials recovery (recycling and reuse). *Life Cycle Analysis* explores place-based solutions that recognize both upstream and downstream effects of buildings. *Building From Waste* presents student-built examples exploring the connections between place and waste. The exercises offer students the opportunity to synthesize their own ideas about designing for materials recovery and to design and build a project within their community.

D.1.1 Discussion: Life Cycle Analysis

The life-cycle approach to design stipulates that ecological, social, and economic impacts be understood across the lifetime of a product, process, material, technology, or service.[1] In architecture this means that these impacts must be considered throughout the lifespan of the building, from site selection, design, and construction to operation and demolition. Although an all-inclusive life cycle assessment would account for all inputs and outputs of materials and energy throughout the duration of the building, design for materials recovery focuses on the what Randy Croxton calls the Final Materials Strategy. Due to the often conflicting variables of cost, aesthetics, relative durability, code compliance, owner's needs and preferences, environmental and social concerns, and surrounding land uses, designing for the future reuse or recycling of a building presents an imposing challenge to the architect.

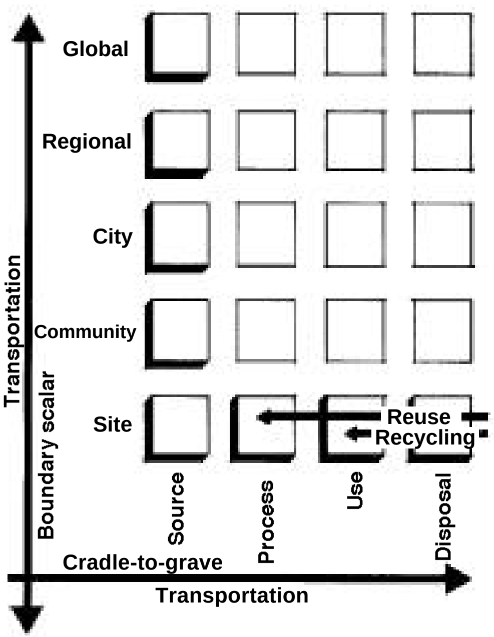


Figure 55: Life cycle analysis framework showing the horizontal "cradle-to-grave" process of materials & the vertical boundary scalar.

For these reasons pointed out in the AIA's *Environmental Resource Guide*, buildings differ significantly from other consumer goods. A building's life span varies according to its construction assemblies and is measured in decades, if not centuries. It is difficult to predict what recovery strategies will be available in the future or what recycling markets will develop. Also, the location and climate of a building are a tremendous consideration for construction methods: buildings can be exposed to high winds, tornadoes, earthquakes, fire, high humidity, freeze-thaw cycles, or flooding.

Life cycle analysis (LCA) provides a systematic framework for tracking technologies, materials, and assemblies from "cradle to grave" (or "cradle to cradle"). Providing as a matrix for assessing environmental impact during the design process, the framework addresses:

(1) sourcing

(2) processing and manufacturing

(3) use and maintenance

(4) reuse, recycling, and disposal

Transportation energy is expended between each phase of the LCA framework. It is also helpful to think of LCA as a way of representing a network of jobs and manufacturers within a regional economy. Adjusting the scale of the LCA framework, one can assess an individual material, a wall system, a building system, a community system, or a regional system.

The last stage of the LCA framework equates most directly to Croxton's Final Materials Strategy. To design for materials recovery, the architect considers embodied energy, durability, disassembly, adaptive reuse, and recyclability. We can interpret these issues in many ways; depending on the application, they can overlap significantly.

Embodied Energy (EE)

The embodied energy of a material, product, or assembly includes the energy required to extract and process the raw materials, manufacture the product, and transport the material and product from source to end use. Examples of building materials with *high* embodied energy are concrete, asphalt, metals, glass, and petroleum-based thermoplastics used as siding, flooring, insulation, and vapor barriers. Building products with *lower* embodied energy include wood, wood fiber, agricultural fiber, reused materials, and many recycled-content and byproduct-based products; energy inputs for the latter two are much lower due to greatly reduced processing energy. Reused materials are usually sold "as-is," while recycled materials often take advantage of the previous energy inputs required to upgrade raw materials. For example, reprocessing aluminum from scrap takes just six percent as much energy as making it from bauxite ore.[2]

The life cycle of a reused, recycled-content, or byproduct-based material begins as soon as it is "picked out of the trash can." This important distinction removes a large portion of the embodied energy burden; however, the manner in which it is incorporated into a building assembly may result in significantly higher energy inputs. For example, Faswall is a permanent wall-form block manufactured from 90% wood waste and 10% Portland cement. Although the Faswall blocks alone may have relatively low embodied

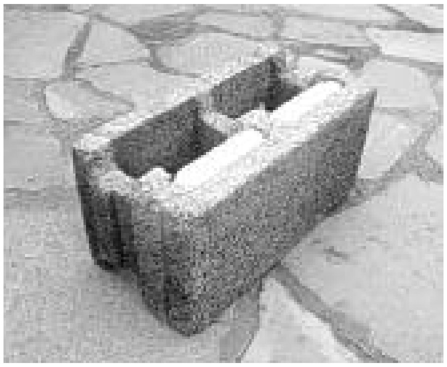


Figure 56: Faswall wall-form block manufactured from recycled wood waste

See **B.1.1 Discussion: C&D Materials Recovery** *and* **Appendix I: Recycling Markets**

entropy

1. A measure of the amount of energy unavailable for work when converted from one form to another
2. Inevitable and steady deterioration of a system or society.

energy, the overall wall assembly includes polystyrene insulation, reinforcing steel, and concrete grout (0.25 ft^3 per ft^2 of wall area). The desirable attributes of the energy-rich reinforced concrete and polystyrene must therefore factor heavily in the design. Although reinforced concrete contributes to a high embodied energy, its strength below grade and thermal mass are positive features that contribute to its long-term durability. One should also account for the amount of operational energy conserved by a material. While polystyrene insulation requires relatively large amounts of manufacturing energy, the heating and cooling energy conserved by its use may offset the initial energy input. In summary, although embodied energy figures improve ecological awareness and environmental responsibility, they cannot be examined in isolation.

Recycling

The natural environment serves as our final "sink" for the disposal of materials. Recycling effectively reduces the level of materials released to the environment, decreases our dependency on virgin material sources, and develops sustainable economies. The success of recycling relies not only on effective recovery strategies and markets for recovered materials, but also on the availability of materials that are easily recyclable. Building materials that can be processed in a relatively pure form offer a higher recycling return than composites. This distinction in purity encourages actual recycling rather than down-cycling, which increases entropy. For example, relatively clean lumber off-cuts should be recycled into high-value particleboard or finger-jointed studs, not down-cycled into hog fuel or landscaping mulch — those high-entropy end-uses are best suited to land-clearing or logging debris.

A century ago, U.S. industry used only about 20 elements of the periodic table; today, it uses 92 elements.[3] Before the age of industrialism, materials were derived primarily from stone, wood, grasses, and earth. Unwanted structures could simply return to the soil. Today, very few of our modern materials are biodegradable. Instead, emerging technologies generate highly engineered composites designed to meet a broad range of performance standards. The snack chip bag is a good example of a complex material with demanding performance criteria. Only 0.002 inches thick, the bag is composed of nine layers including polypropylene, polyethylene, co-polymers, inks, and aluminum. This high-tech packaging blocks moisture, oxygen, and light; resists puncture; and resists potential tampering.[4]

While building materials may not express the same level of complexity as a bag of potato chips, recycled and byproduct-based materials are steadily evolving as composite materials using either organic (formaldehyde and isocyanate resins) or inorganic (mineral or polymer-based) binders. Examples of organic composites include framing materials using wood-fiber strands and laminated wood veneers; panel products using oriented strand board or plywood; and a host of medium-density fiberboards using wood or straw. Inorganic composites include an assortment of fiber-cement products for roofing, exterior siding, wall-form blocks, and interior wallboard; and fiber-impregnated plastics designed primarily for outdoor deck applications.

For more information on strawboard, see **Appendix II: Straw Building Materials.**

The evolution of composite materials is influenced by our desire for higher performance and greater utilization of post-consumer and industrial wastes. Diverting composite building materials from the landfill or incinerator requires extensive recovery networks so they can be recycled as the same product, lateral exchanges so they become feedstocks for some other product, or down-cycling the material to a relatively low-value use such as drainage fill or boiler fuel.

Durability

The endurance of a material or assembly determines how often it requires maintenance or replacement. Generally speaking, materials or assemblies with high embodied energy are very long-lasting and should be used in such a way that recognizes this quality. Stewart Brand describes permanence broadly in terms of “high-road” and “low-road” buildings. Stone, masonry, and concrete are considered high-road materials that require minimal maintenance if properly detailed. These materials give shape to high-road buildings that provide years of service given a flexible enough form. Otherwise, as in the case of parking garages that are difficult to adapt to new functions, they become massive derelicts that are demolished at great expense. Appreciable examples of enduring architecture abound. The works of Tadao Ando, Mario Botta, Louis Kahn, Alvar Aalto, and Louis Barragan provide models that combine durability and elegance.

Figure 57: Kimball Art Museum by Louis Kahn, Fort Worth, Texas

Most often, we see the combination of "high road" structures with "low road" veneers. In the 1950s and 1960s, older brick buildings in need of pointing often received a new facade of inexpensive metal panels that quickly faded. Recently, the high-tech / low-road enclosure of choice is exterior insulation and finish systems (EIFS) composed of foam panels and synthetic stucco. Whenever shopping malls or corporate headquarters feels the need for a "facelift," their reinforced concrete or masonry shells are redone with Dryvit. In the case of EIFS, different materials are bonded to one another, making separation and recycling prohibitive. Kevin Lynch suggests that

> managing duration will include seeing that all components of a product have similar lifespans and synchronously waste together or that components of an object are separable, some of them easily wasted and the others easily recycled.[5]

Disassembly

See **C.2.1 Discussion: Conservative Disassembly**

As an accumulation of materials, buildings provide a means of storing resources for future use. For these resources to be reusable or recyclable, the construction systems should be designed in such a way that allows for conservative disassembly. "Design for disassembly" or "design for reuse" (not to be confused with "adaptive reuse") have become increasingly important in the manufacturing sector. Companies are more focused on ease of assembly than disassembly because most products are not recovered—they're wasted. Recently, Germany has mandated "take-back" legislation requiring manufacturers to be attentive to life cycle issues. Previously, a manufacturer could be unconcerned with its product's value once it had served its purpose, but take-back legislation requires industry to reevaluate: Can the product be repaired? Can individual parts be recycled or reused in other products? Is the product capable of decomposition?

See ***C.2.2 Case Study: The Sauna Experience***

These questions and others that pertain to the disassembly of architecture need answers in the form of elegant and pragmatic design solutions. Because buildings are capital-intensive and extremely bulky, it is difficult to imagine them as products subject to "take-back" and disassembly. The open-ended building systems being developed in

Europe and Japan and the modular and manufactured building sector offer a glimpse at this approach. Conventional site-built approaches to design for disassembly are usually based on post-and-beam construction types, which most effectively separate structure from enclosure. The Advanced Green Builder Demonstration project by the Center for Maximum Potential Building Systems in Austin, Texas, uses design for disassembly as the basis for its overall form.

See **D.1.2 Case Study: Advanced Green Builder Demonstration House**

Adaptive Reuse

Buildings are complex assemblages of many different materials. Although designing for disassembly can assist in making future changes less wasteful, the fact that buildings incorporate so many different materials at such great expense leads us to examine how they can be more readily adaptable to subsequent change. One half of designing for adaptive reuse deals with the "forgiveness" of the material, while the other half involves the flexibility of space.

See **C.1.1 Discussion: Adaptive Reuse**

In the first design charettes for Wal-Mart's Eco-Mart in Lawrence, Kansas, one of the first questions raised was "What will the store be when its Wal-Mart lifetime is over?" William McDonough, architect and eco-philosopher, replied, "Why not design it for adaptive reuse and avoid the unsustainable practice of disposable architecture?"[6] Wal-Mart is notorious for opening multiple stores on a daily basis, and the possibility that some of these stores might be closed in the near future is worth considering. To accommodate its next life, the Eco-Mart can adapt to future apartments. The concrete blocks are spaced to allow for future windows, and the ceiling height permits a second story. McDonough has also employed this strategy in a proposal for a day care center in Frankfurt, Germany. In addition to a number of socially and environmentally sensitive features, the day care center is designed with "multiple potential uses": It can be converted into three attached houses, six apartments, or 12 flats.[7]

Figure 58: Environmental Works Community Design Center reuses an old firehouse in Seattle for its office

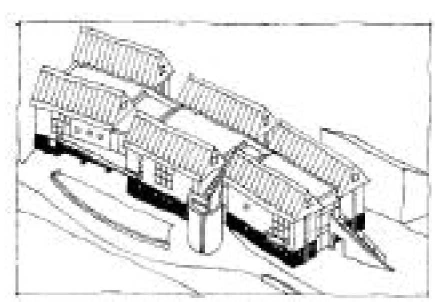


Figure 59: proposal for day care center by William McDonough, architect

D.1.2 Case Study:
Advanced Green Builder Demonstration Project (Austin)

The Center for Maximum Potential Building Systems ("Max's Pot"), co-directed by Pliny Fisk III and Gail Vittori, integrates the concept of industrial ecology with bioregional design. Max's Pot consists of a multidisciplinary team that seeks to network material, energy, and informational flows within a biogeographical context at all scales of development. Whether a single product, building system, community, or region, the goal is to demonstrate how available physical resources and natural processes can be best managed to create sustainable economies.

Figure 60: Advanced Green Builder Demonstration Project, Austin, Texas (CMPBS)**.**

The Advanced Green Builder Demonstration project (AGBD) designed and built by Max's Pot addresses energy and water usage, climate, and building materials. The use of technologies that are locally available, renewable, reusable, recyclable, or biodegradable makes this house unique. At the heart of the design process is a flexible framework called "GreenForm." This regionally derived, expandable post-and-beam system supports a variety of materials that are chosen using the life cycle approach.

For the AGBD project, Max's Pot developed an open-ended framing system of rebar posts and beams made from the recycled steel of old cars. The system is a new engineering technology for steel reinforcing bars that forms an assortment of interchangeable framing members, like the classic Erector set. A builder can unbolt parts and reuse them or add new lengths to create additions. The infill walls of the house demonstrate nine different systems made from combinations of underutilized natural, recycled-content, and byproduct-based materials.

Some of the materials and methods are re-introductions of older technologies, such as:

- stabilized earth
- rammed earth
- adobe
- straw-clay *fachwerk* for "half-timbered" frames
- straw bale construction

Others are adaptations of traditional materials, including:

– mesquite floor tiles
– 4'x8' panels of mohair wool sandwiched between strawboard

The minimal processing and organic composition of these materials prevent them from becoming burdensome wastes —in most cases they can simply be plowed into the soil.

The more highly processed materials include:

– Calcrete: A composite made of caliche, a local material high in calcium carbonate, and coal fly ash, a byproduct of coal-burning power plants.
– AERT: A wood polymer composite made from waste juniper fiber (from a nearby cedar-oil producer) and recycled post-consumer polyethylene bottles.
– Steel: The rebar framework, floor and ceiling joists, corrugated roofing and siding, gutters, flashing, and cisterns are made of steel that is 60-97% recycled from crushed automobiles.

The combination of cisterns for collecting sparse rainfall, open breezeways for ventilation, trellises for shade, landscaping for the wastewater, and materials that are locally derived, reusable, and recyclable results in a house form exquisitely adapted to its present and future. The Advanced Green Builder Demonstration project for Austin, Texas, is a compelling and inspiring example of regional architecture that demonstrates how life cycle and bioregional analysis serve as a conceptual basis for design.

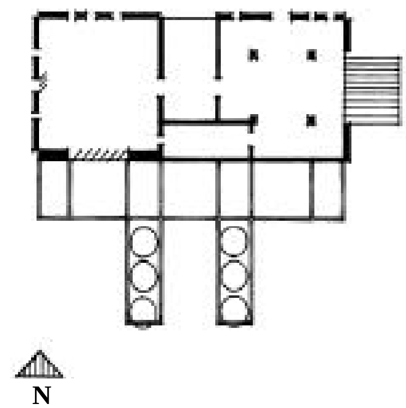


Figure 61: Ground floor plan of the Advanced Green Builder Demonstration Project.

D.1.3 Exercise: Life Cycle Design

Figure 62: The author's 5th-year design project that investigates energy and material flows at the house scale (bottom) **with full-size mock-up of wall system using rammed earth, automobile tires, and straw bales sandwiched between "box-columns"** (top)**.**

Objective

To develop one's dexterity in life cycle design issues related to materials recovery: embodied energy, durability, disassembly, adaptive reuse, and recyclability. While a quantitative approach to life cycle analysis suits the needs of scientists, this type of modeling is both unnecessary and undesirable during the design process. However, critical thought as to the basic cause-and-effect relationships of alternative materials and construction assemblies is the responsibility of the architect.

Preparation

Because this exercise encompasses all the critical issues of materials recovery, it is expected that a basic review of this module in its entirety precedes any design project. Any or all of the discussions, case studies, and exercises will be helpful in preparation for a studio project. Exercises A.2.2 (Serial Materials Recovery) and A.3.2 (Regional Material Streams) provide an important knowledge base of local and regional recycling economies and material flows. The design process will be more meaningful if well-grounded within a network of local and regional possibilities.

Execution

To avoid the frustrating "it depends" syndrome often attached to the noisy activity of interrelated life cycle issues clamoring to be addressed, it is advised that the student focus his or her investigation on a single issue. This prevents the unnecessary "wallowing" that so often occurs in the attempt to responsibly include as many issues as possible. Choosing a design-for-disassembly scheme, for example, does not exclude embodied energy, durability, adaptive reuse, and recyclability. Instead, it sets up a clear conceptual hierarchy within which the "normal" spatial and compositional elements of light, scale, texture, rhythm, unity, etc., take form.

D.2.1 Discussion: Building from Waste

> Most men appear never to have considered what a house really is, and are actually needlessly poor all their lives because they think that they must have such a one as their neighbors.
>
> —*Henry David Thoreau*

When we think of making buildings from waste, the images that come to mind are Third World squatter settlements derived from the discards of First World consumption, Heineken Brewery's quirky WOBO (WOrld BOttle) architecture, and Michael Reynolds' rammed-earth automobile tire Earthships. Although these examples may not reflect the "quality of life" mindset espoused by an affluent society, they are connected by a social as well as material sensitivity and represent ideas about how we waste.

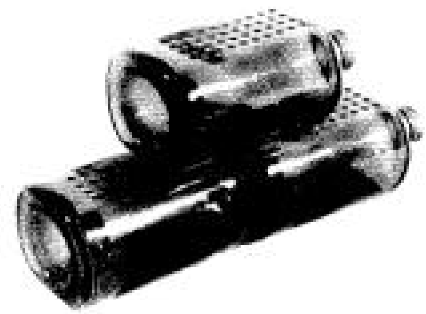


Figure 63: WOBO bottle construction

Alfred Heineken saw the poverty of Curacao squatter shacks in 1960, which prompted the redesign of a beer bottle capable of serving as a "brick" when empty. The bottle never continued past a prototype, and the idea of designing products for multiple uses and exploiting their widespread production and distribution networks has yet to be accomplished. Only small examples of indirect secondary use exist. For example, during the 1930s, bulk flour was packaged in colorful printed fabrics because people made their clothes from flour sacks.[8]

Figure 64: Earthship near Boise

Taking advantage of byproduct resources, the architectural forms of Michael Reynolds' Earthships evolve from the potential of the material and skill of the builder. Rammed earth tire construction creates a high-performance building system and invests heavily in human energy. The thermal mass capability of rammed earth coupled to the elasticity of automobile tires provides both thermal comfort and seismic stability, while remaining within economic reach of unskilled people willing to contribute their own labor.

Building components derived from resources that would ordinarily be wasted can be summarized into three major categories.

1. *Reused materials:* Salvaged materials that are reused after minimal reprocessing

2. *Recycled-content materials*: Highly processed composites usually containing a post-consumer-recycled feedstock held together by some form of binder.

3 *Byproduct-based materials*: These employ minimally processed agricultural or industrial byproducts.

Examples of architecture students' design / build projects derived from local wastes provide the framework for this discussion. These include a house for $501.70 by architecture students at the Rensselaer Polytechnic Institute in the 1970s and the recent work of the Remote Rural Studio at Auburn University.

A House for $501.70: RPI, 1976

Under the supervision of professor Martin Pawley, architecture students at Rensselaer Polytechnic Institute conducted many building experiments using common, extremely low-cost waste materials. A local search for supplies revealed a number of constantly "renewable" resources within two miles of the campus. Every week the local newspaper dumped 150 newsprint cores, food outlets on campus generated 600 No. 10 cans, Star Textiles produced 600 pounds of steel strapping waste, Pawling Rubber Company threw away 2'x2' neoprene rubber mold linings leftover from the manufacturing of bushings, and empty glass bottles were never in short supply. After a few small experimental projects, the students approached their "client," Dora Crouch (a faculty member and garbage enthusiast), and offered to build her a 500 ft^2 house on campus for about 10 cents per square foot.[9]

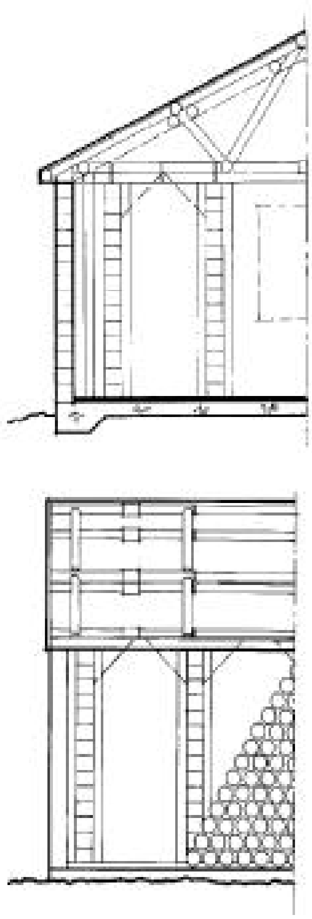


Figure 65: Section (top) **and elevation** (bottom) **of the Dora Crouch house.**

The design of the house was extremely simple due to the experimental nature of the structural system. The framing was constructed from newsprint cores, with No. 10 cans used as splices and spacers. Reused steel strapping held the framing elements in compression. The entire system utilized the materials with minimal modifications; their dimensions playing a key role in the overall design. Besides an inexpensive strapping device, no other tools were needed. Thick layers of cardboard followed by polyethylene sheeting provided the necessary underlayment for the _-inch thick rubber mold linings, which were nailed to the roof like shingles.

For walls, No. 10 cans were laid like bricks in cement mortar interrupted in three locations by a south-facing bottle wall, a door to the east, and a single window on the west side. The cans were plastered over with a thick, sulfur-based "paint." Although sulfur is a natural material found in abundance, it is also a byproduct of petroleum refineries. Sulfur's high strength and rapid setting properties make it a suitable substitute for Portland cement.[10]

The Dora Crouch house stood uninhabited for two years before it was demolished to make room for a storage facility. Although the house was a target for vandals, it remained structurally sound and could have stood for many years. Regardless of how unpolished the product was, the students demonstrated incredible ingenuity and resourcefulness using locally available materials at minimum cost. Prior to widespread industrialism, all building materials developed in this manner.

Remote Rural Studio: Auburn University, 1993

Every year, teams of architecture students from Auburn University leave the campus to design and build housing for low-income people. The Remote Rural Studio, led by architect and professor Samuel Mockbee, gives students the opportunity to, in Mockbee's words, "plug into the muse responsibly." Working with Community Service Programs, deserving clients, and local businesses, the students create invaluable linkages that inform the design and construction process. Since the start of the program in 1993, the students have built two houses and a chapel and renovated a building for a social service agency.

Building from cheap and plentiful waste materials has become a necessity for the students, who work with minimal funding. For the 850 ft^2 Bryant House in Masons Bend, the students had to cover all the material costs with a $15,000 grant from the Alabama Power Company. After researching low-tech solutions, the students decided to make use of an abundant local agricultural byproduct: they used load-bearing straw bales for the exterior walls. In addition, a 5'x8' smokehouse resembling LeCorbusier's chapel at

Figure 66: Bryant House and smokehouse by Remote Rural Studio, Auburn University (Timothy Hursley).

See **Appendix II: Straw Building Materials** *and* **C.3.1 Discussion: Reusing Salvaged Materials.**

Ronchamp was constructed for about $1 per square foot. This small outbuilding is composed of 100% reused materials including concrete shards, curved beams from a Quonset hut, and old road signs from the Alabama Transportation Department. Inspired by the spiritual qualities of the smokehouse, several students went on to build an open-air chapel using automobile tires, reused steel I-beams, salvaged wood trusses, and sheet metal from an old barn.

Figure 67: Chapel by Remote Rural Studio, Auburn University (Timothy Hursley)

The work of the Remote Rural Studio is not a scientific process of linking wastes with opportunities, but a social endeavor of developing relationships within a community while hunting for building materials. Tapping into the local waste material flow is only one aspect of this development. According to George Gintole, an associate professor of architecture at the University of Texas at Arlington, "With all the work that needs to be done in rural areas, this is a worthy attempt to repair what architectural schools have left out."[11]

D.2.2 Case Study:
The Stookey Plant Nursery (Moscow, Idaho)

Supported by a grant from the National Pollution Prevention Center for Higher Education at the University of Michigan, I designed and built a 450 square foot plant nursery at Stookey's Feed and Garden in Moscow, Idaho. The budget was approximately $14 per square foot for the building materials. My labor, and the labor of occasional volunteers and workshop participants, was donated.

The primary goal was to investigate the available and potential reuse and recycling network in order to design and build from a "soft palette" of salvaged, recycled-content, and byproduct-based materials. The term "soft palette" is used to recognize a range of local and regional wastes whose building potential may be ephemeral (such as salvaged materials) or experimental (such as straw bale construction). This soft palette influenced by the life cycle design issues of embodied energy, durability, adaptive reuse, disassembly, and recyclability became the basis for design. The secondary goal was to develop a dialogue about recycling and reuse between public agencies, building inspectors, private businesses, design professionals, builders, and members of the community.

Figure 68: Exterior views of Stookey's Plant Nursery in Moscow, Idaho.

The Soft Palette

To develop the soft palette, I identified regional and local material streams and potential wastes, including regional and local industry, manufacturing, reuse and recycling operations. The two major regional industries, timber and agriculture, are significant generators of wood waste and straw residue, neither of which are currently processed as building materials in the Inland Northwest. Instead, wood chips and sawdust are sold for relatively low-value end-uses such as mulch, compost bulking agents, and boiler fuel; the current markets for straw include erosion control and animal bedding.

I chose a number of commercially manufactured building products that could conceivably "close" these material streams and enhance the regional "waste" economy. These products include:

– *Faswall*, made from 90% wood waste and 10% cement molded into a low-density interlocking permanent wall-form block

salvaged open-web steel trusses

partially below-grade reinforced concrete wall using Faswall wall-form blocks

mortared bottle infill between Faswall and straw bale walls

stuccoed straw bales for R-40 infill walls

WheatBoard medium density fiberboard for interior finish

salvaged doors, hinges, and clerestory glass

aluminum litho-plates for shingle siding and soffits

salvaged wood for posts and beams

reused broken concrete for floor pavers

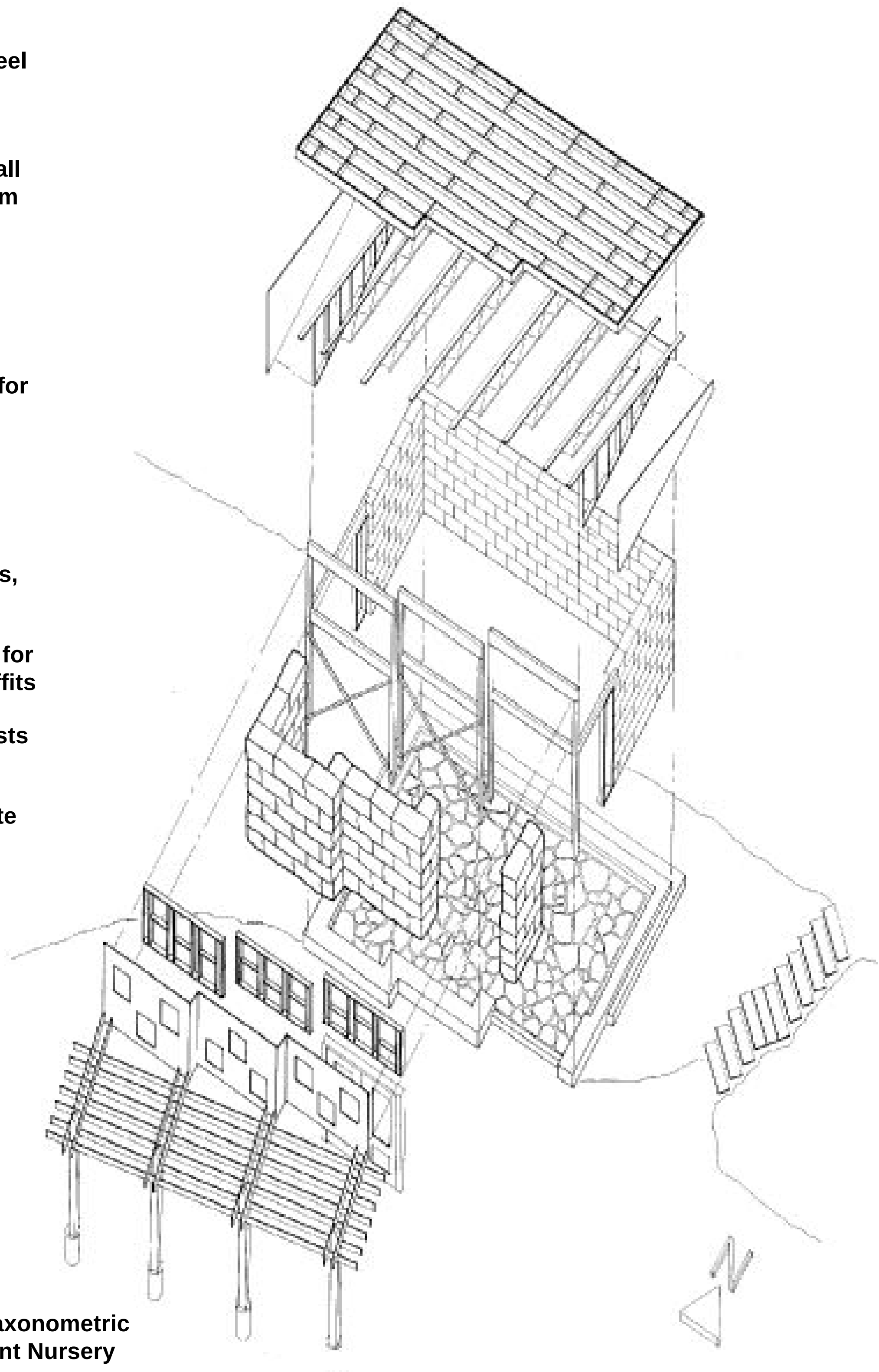


Figure 69: Exploded axonometric view of Stookey's Plant Nursery

– *WheatBoard*, a medium-density fiberboard made from straw

– *Trex*, extruded from sawdust and recycled plastic into dimensional lumber and decking material

The *Faswall* and *Wheatboard* were shipped from Ottumwa, Iowa, and Wahpeton, North Dakota, respectively. The nearby Washington State University Wood Materials Lab donated four-foot lengths of five-quarter-by-six inch *Trex* decking boards that were left over from structural testing. The straw bales to be used for infill walls are abundant regionally and locally.

It is important to emphasize that although materials were imported from other regions, a plentiful and underutilized resource base of wood waste and straw exists within the Inland Northwest region. Several promising feasibility studies have been conducted for straw board manufacturing in both Idaho and Washington, and recent mill closures offer low-cost siting possibilities. In fact, Midwest Faswall in Ottumwa, Iowa, was sited in a vacant brick factory, thus demonstrating the compatibility of both sustainable economic growth and the reuse of existing infrastructure.

Figure 70: Wood waste at the University of Idaho chipper facility could be recycled into building materials similar to this Faswall wall-form block, which is manufactured from waste wood and cement.

Manufacturing businesses are few in Moscow, Idaho. It is primarily a service-oriented university town with central grain- and pea-processing facilities. I discovered that:

– the local newspaper, *The Moscow-Pullman Daily News*, produces 24"x36" aluminum lithoplates as a byproduct of the printing process,

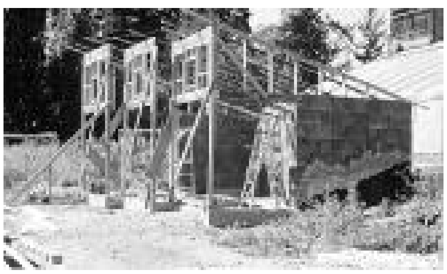
– the Moscow Food Co-op generates dozens of open-weave plastic onion bags every month (it has sponsored idea-generating competitions to promote reuse of these sacks), and

– local contractors deliver broken, unreinforced concrete sidewalk and other miscellaneous rubble to a number of "fill" sites.

I used the lithoplates as shingled siding and soffits, the onion sacks as filter fabric over crushed glass cullet drain fill, and sidewalk shards as a "flagstone" floor.

An investigation of the local and regional reuse businesses, recycling operations, and current demolition projects yielded an ephemeral supply of used dimensional lumber, short lengths of heavy timber, open-web steel joists of three separate spans, and factory clear corrugated roofing seconds. Locally, Wasankari Building Recyclers operates a retail yard in Moscow, while Brown's Used Building Materials in Spokane operates one of the largest salvage yards in the Pacific Northwest. In addition, The Moscow Recycling center continuously receives unsaleable green glass bottles and glass cullet (processed glass), which I used for mortared infill (bottles laid flat like bricks) and drainage fill.

Figure 71: Setting floor "pavers" and Faswall blocks . . .



post-and-beam frames and open web steel joists in place . . .

. . . and strawbale infill and Faswall waiting for stucco. The framed portion above will be sided with aluminum litho-plates.

The Building

To keep costs low, a four-foot trench was excavated beneath the grade-level foundation and filled with compacted three-inch graded crushed rock. An additional six to eight inches of five-eighths minus crushed rock was used to level the entire building footprint area of the site. Perforated plastic pipe was placed near the bottom of the trench, directing water to a drywell fabricated from a reused perforated 55-gallon drum. Although not yet an alternative source of graded aggregate in Moscow, recycled concrete can potentially be utilized in this rubble trench foundation system. A poured-in-place concrete grade beam atop the rubble trench completed the foundation system. Sidewalk shards, a few bricks, and pieces of sandstone block were set on the crushed rock base like puzzle pieces and then grouted with a mixture of crushed rock and sand, allowing for drainage.

Taking advantage of the below-grade durability of reinforced concrete, Faswall was used to form the eight-foot-high, -shaped retaining wall on the north, east, and west sides of the nursery. The wall is bermed to four feet. The process of laying the blocks went quickly and easily due to the interlocking design. Besides leveling the first course, no mortar is required. The blocks are lightweight and breathable, and they cut "like butter" with normal carbide-tipped blades. It was necessary to notch out pockets to accept the post-and-beam framework. Although I applied a 3-coat cement stucco to the Faswall, any choice of finish or siding can be screwed on directly. The Faswall blocks were grouted in two lifts; the first by hand and the second with a boom pump. Entirely unbraced, the formed walls quivered only a little under the strain of wet grout injected into the cores. The geometry is kept simple such that this massive element can more easily adapt to future needs. Reinforced concrete cannot be easily disassembled. Should demolition occur, this construction assembly would require mechanical separation using crushers, magnets, and blowers yielding a lightweight insulative aggregate, pieces of reinforcing steel, and little bits of polystyrene.

The structure was completed with a post-and-beam system using salvaged timbers for the spanning members. The combination of non-dimensional salvaged four-by-tens and four-by-sixes caused the exterior sheathing surface of the framed portion to be somewhat uneven, but the buckling of the thin aluminum lithoplate siding (which was attached like shingles) pleasantly concealed these discrepancies. Straw bales were stacked in a running bond, pinned with rebars, and notched to accommodate the posts up to a height of eight feet. The addition of diagonal steel strapping bolted to the posts and beams created a braced frame. Stucco covers the straw bales and is colored by ferrous sulfate; the mottled reddish hue is a byproduct of the oxidation process.

Figure 72: Notching and fitting bales around the post-and-beam framework.

The separation of structure and enclosure acknowledges the possibility of conservative disassembly. Should this portion of the building require removal, the stucco skin would be shattered (with some effort), peeled away from the bales (heavy-gauge, -shaped pins fasten the stucco wire to the bales), and mechanically pulverized to separate the steel reinforcing netting from the fine aggregate. The bales would be unstacked and mulched, and the steel rebar pins and x-bracing would either be recycled or reused.

Figure 73: Refinished salvaged doors.

The window frames were hand-built from cedar and enclose fixed panes of glass salvaged from a disassembled greenhouse facility at the University of Idaho. Two solid wood doors were purchased from Brown's Used Building Materials in Spokane; a water-based chemical stripper removed years of paint and varnish to reveal clear, vertical-grain fir. Additional daylight to the nursery space is provided by a clear corrugated acrylic shed roof. The open-web steel joists can accommodate an increased dead-load should the building every be retrofitted as a heated space.

At the time of this writing, the building is almost complete. The interior remains unfinished awaiting additional stucco over the straw bales and WheatBoard over the framing. On the exterior, a south-facing trellis from salvaged eight-by-eight timbers and framing leftovers will provide a sheltered area for educational signage describing the building process.

Figure 74: A community open-house was held to allow the public to view the “exposed” materials.

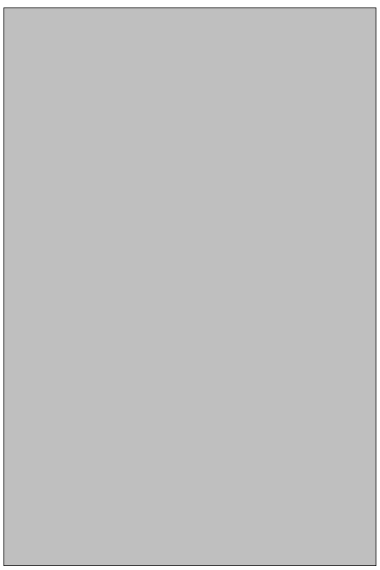


Figure 75: Interior view showing finish work in progress, including plaster over straw bales and medium density straw fiberboard over the wood framing.

Community Outreach

The goal of engaging the community has been met. Early on in the planning process, I approached the city building department with sketches, literature, and engineering data regarding strawbale and Faswall construction. I discussed my desire to utilize as many salvaged materials as possible, including using salvaged timbers for structural applications. Department staff were open to the idea of using alternative materials, and they appreciated having their concerns addressed beforehand. When it came time to apply for a building permit, there were no surprises: the building department agreed to the use of salvaged materials for structural applications if I scheduled their inspection prior to installation.

Before commencing, I organized a presentation on straw-bale construction and the recovery of building materials. A group of 40–50 community members showed up at this lively discussion. Later, when I scheduled a “wall-raising” workshop, approximately a dozen returned to help and learn. When it came time to stucco the walls, I held another workshop.

Two open houses were held, one in November of 1996 and another in April of 1997. These day-long events were publicized through the county-wide solid waste quarterly, the local newspaper, and public-access television. A table of free sample materials, snacks, and resource packages was set up inside the building. Each open house attracted 50–100 people. The second open house in April offered plastering demonstrations and the opportunity for some hands-on experience.

As a method for researching the recycling and reuse of buildings, the design-build process incorporates, to some degree, all aspects covered within this module. The informal web of people and places that contribute to a recycling and reuse project has a cumulative effect. Stookey’s Plant Nursery evolved from a culmination of conversations around the community that, in time, revealed sources of materials. On a more personal level, it has let me express some of my own values and beliefs through architecture.

D.2.3 Exercise: Design/Build

Objective

There is a widespread tendency among many design studios in architecture not to consider the materials as part of the project's conception. Aside from deciding on a loose list of possibilities, materials are too often dismissed. The objective of this exercise is to experience the complete process of design and construction, incorporating local and regional opportunities and barriers as they relate to recycling and reuse. The students also become teachers since the process of building with "new" materials attracts public attention. The public's perceptions of the built project provide necessary and immediate feedback for the students.

Preparation

Unfortunately, the design/build process in an academic setting inevitably suffers from insufficient time. Given a tight schedule, there is always the risk of falling behind, resulting in a laborious struggle to finish in a hurry (welcome to architecture school). Juggling course commitments and other responsibilities, students rarely have enough gaps during the semester for construction; therefore, it's helpful to spread the process out over a full year with several groups of students. This "tag team" approach is used by the Remote Rural Studio at Auburn University.

Execution

Scaling the project down to a manageable size can help bring the process to closure. Once a group is assembled, assess the skill levels and tool resources that are available. Also, having a clear goal with definitive project boundaries and roles that are agreed upon by all the participants will avoid unnecessary delays once construction begins.

D.3.1 Endnotes for Design for Materials Recovery

[1] Braden R. Allenby and Deanna J. Richards, eds., *The Greening of Industrial Ecosystems* (Washington: National Academy Press, 1994), 13.

[2] David Wann, *Deep Design: Pathways to a Livable Future* (Washington: Island Press, 1996), 148.

[3] Deanna J. Richards and Ann B. Fullerton, eds., *Industrial Ecology: U.S.-Japan Perspectives*. (Washington: National Academy Press, 1994), 24.

[4] Wann, 169.

[5] Kevin Lynch, *Wasting Away* (San Francisco: Sierra Club Books, 1990),188.

[6] Wann, 147.

[7] William McDonough, "A Boat for Thoreau: Architecture, Ethics, and the Making of Things," *Business Ethics* (May / June 1993): 28.

[8] Forrest Wilson, AIA, "Building With the Byproducts of Society," *AIA Journal* (July 1979): 41.

[9] Martin Pawley, *Building for Tomorrow* (San Francisco: Sierra Club Books, 1982), 3.

[10] Pawley, 118.

[11] Sydney LeBlanc., "From Humble Sources, Earthy Elegance Springs," *The New York Times* (Thursday, April 18, 1996): C6.